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EDITORIAL

AVE ATQUE VALE

IN our previous issue the attention of readers was drawn to the Editorial, Publication and Subscription changes which will take place on completion of the current volume of *Tropical Agriculture*. This issue is the last which will be published and printed in Trinidad.

Tropical Agriculture has undergone, since its inception, several changes in character, scope and format. We believe that these changes have been mostly for the better and that those which are about to take place will result in further improvement.

During the thirty years of its existence *Tropical Agriculture* has, we trust, achieved in a measure the aims set out in the first issue, and has "displayed in broad yet exact terms, understandable by all classes of readers, what tropical agriculture really means, the latest discoveries of research and the many problems that await scientific solution." As the journal of the Imperial College of Tropical Agriculture it is natural that many of its pages

should have been devoted to accounts of work done at the college and it is perhaps fitting that this last issue from Trinidad should consist in its entirety of reviews and articles submitted by members of the college staff.

The contribution of the Imperial College to the advancement of tropical agriculture has not, however, been through research alone but also through the training of scientists who now work throughout the colonial territories and in many other parts of the tropics. These alumni have themselves trained local assistants to undertake an ever increasing part of the agricultural extension work and are now devoting more of their time to the investigation of some of the varied problems with which they are faced.

It is hoped that accounts of many of these investigations will be published in the new series of *Tropical Agriculture*, and that thereby not only will its aim be furthered, but also its sub-title—the Journal of the Imperial College—will come to have a wider meaning.

THE I.C.T.A. ANNUAL DINNER

Past students, staff, members of the Governing Body, and friends of the Imperial College of Tropical Agriculture met on Friday, 17th July, for the second annual dinner of the College. A toast to the College was proposed by W. B. L. Monson, C.M.G. (Assistant Under-Secretary of State, Colonial Office); and A. B. Killick, C.M.G. (Professor of Agriculture), replied for the College. Sir Geoffrey Evans presided and expressed his pleasure at seeing no less than seventy people present. He hoped that the dinner would have continued success annually and that every effort would be made to keep former students informed about it.

It is now hoped to hold the dinner at 7.30 p.m. at the Royal Empire Society on the third Friday in July every year, so long as it receives popular support, and the Assembly Hall of the Royal Empire Society has been reserved for next year. The dinner is open to all who have been associated with the I.C.T.A. as Students, members of the Senior Staff, or members of the Governing Body, and to guests of either sex introduced by them. For the convenience of people on home leave who may not be fully equipped, the dress will be "lounge suit".

A small surplus of funds (approximately £6) resulted from the Dinner of 1953. It is proposed to devote this to the cost of arrangements for the next dinner, and to the cost of compiling a register of "members" which might form the basis for an I.C.T.A. Association.

Requests for further particulars should be addressed to Mr. J. E. Mayne, Room 723, Colonial Office, Sanctuary Buildings, Great Smith Street, London, S.W.1.

REVIEW ARTICLES AND BOOK REVIEWS

TROPICAL CROPS

HEVEA

"Thirty Years of Research in the Far East"

By M. J. Dijkman, *University of Miami Press, University of Miami, Coral Gables, Florida.* 1951. *Pp.* xxii + 329, *with* 130 *figures and plates, and* 108 *tables. Price* $6.00. (U.S.)

This is an excellent and comprehensive monograph embodying the results of scientific experimentation and research on *Hevea brasiliensis* and the technique of rubber growing in Indonesia up to the outbreak of war with Japan in 1941. The author was engaged in research and extension work for the West Java Experiment Station at Buitenzorg, as selectionist and as head of the extension service for South and West Sumatra and the Riouw Archipelago.

After a brief account of the history of the rubber-growing industry in the Far East and of the development of research thereon in Indonesia, and an outline of the economic importance of the industry to Indonesia, thirteen chapters are devoted to a very well documented and plentifully illustrated treatment of the various factors, fundamental and practical, on which the economic production of rubber from Hevea depends. An account is given of the researches and experiments carried out in Java and Sumatra, on such subjects as growth studies, vegetative and generative propagation, improvement by selection and breeding, soil management and manuring, planting systems, latex physiology, tapping, diseases and pests, and the many other factors involved in commercial rubber growing.

It is understandable that the material presented in this book should be drawn almost exclusively from the results of Dutch experimental work. Moreover, as pointed out by Dr. R. D. Rands in the Foreword: "Every investigator of plantation *Hevea* in this hemisphere will recall his difficulties in trying to review the Eastern literature that is so widely scattered and so preponderantly in the Dutch language . . . . . Because so few English-speaking persons read the Dutch language, much of the fundamental Hevea research in Indonesia has never become widely known." For the English-speaking reader, therefore, this book is specially valuable. But in studying it he should realise that its contents would be more accurately described if its subtitle had been "Thirty Years of Research in *Indonesia*". Although the Dutch certainly led the way in Hevea research, important contributions have been made in the past 27 years, since its establishment in 1926, by the Rubber

Research Institute of Malaya at Kuala Lumpur, and its sister institute in Ceylon, yet this British work receives only scanty notice in this book. It is not suggested that this work has been deliberately cold-shouldered by the author ; passing reference is indeed made to it in many places, but many important developments and findings not paralleled in the Dutch work are overlooked. The fact is that the book is primarily what Dr. Rand describes it as in his foreword, a summary of 30 years of Dutch East Indian rubber research. It is no reflection on that work, which in quality and quantity is second to none, to point out that in order to obtain a well balanced and complete knowledge of research on Hevea and the natural rubber-producing industry, the publications of the British research institutes must also be consulted.

The treatment of some branches of the subject, notably soil management and manuring, and diseases and pests is somewhat uneven and sketchy in comparison with the more botanical branches of the subject. This is not surprising, having regard to the author's own special field, and to the fact that improvement by selection and breeding is indeed the most outstandingly important part of the subject, and the one in which the Dutch were pioneers and to which they have made the most notable contributions.

One questionable statement appears at the beginning of the book, viz., that by 1940 the average yield of rubber had risen to over 2,000 Kg. per hectare (equivalent to over 1,800 lb. per acre). While it is true that yields at or even above this rate can be obtained from individual trees of improved high-yielding clones or families, or from experimental areas or even some areas of commercial plantations, for the unwary the statement would imply that the overall average yield of rubber in the Far East, or in Indonesia, has reached that level, which is still far from true, remarkable though the increase in yield has been on areas wholly planted with improved clones or families.

It is a very moot point whether the results of research in the Far East can be applied to the development of commercial rubber-growing in the Western Hemisphere so that it can compete with the Far East, even if high-yielding strains resistant to South American Leaf Disease (*Dothidella ulei*) can be got. The results of plantation rubber-growing ventures in South America up to now would not seem to be encouraging.

The book is written in excellent English and very well produced, with a singular scarcity of misprints and a clear and readable type. The photographic illustrations are rather small, and though reasonably clear on the whole, they could with advantage have been much larger.—H.J.P.

BOTANY OF SUGAR-CANE

By C. van Dillewijn. *Waltham, Mass.—The Chronica Botanica Co.;* 1952. *Pp.* xxiii+371. 229 *figures. Price* $6.00 (U.S.)

The book is a well-integrated review of the subject based on over 600 references up to 1951. About one-sixth is devoted to the structure of the cane plant and the rest to its physiology under the headings: Germination, Tillering, Growth, Vegetative composition, Chemical composition, Nutrition, Water, Photosynthesis and Respiration.

Its value could have been much enhanced by including more data on the methods used in obtaining the results recorded; usually for these the reader must be prepared to return to the originals. For a work of this nature, the index could be much improved; a hunt for such entries as *foliar diagnosis, micro-nutrients, cuticle, lignin, vessels, lysigenous cavity,* &c., or their synonyms revealed nothing although mention of all these topics is to be found in the text.

Notwithstanding these (perhaps minor) faults, the book is a useful compilation and should be welcomed by the research worker and student as a general reference. It is well printed on heavy paper and the illustrations (usually those of the originals or adaptations from them) are excellently reproduced.—P.B.H.

AGRICULTURE OF THE SUGAR-CANE

By A. C. Barnes. *Leonard Hill Ltd., London* 1953. *Pp.* 392. 60 *Illustrations Price* 42 *shillings.*

All aspects of sugar-cane production from the breeding of new varieties to the delivery of cane to the factory are covered in this book which has been written by one of the world's leading authorities on the crop.

The material is presented in a way which builds up progressively with each succeeding chapter, a complete, and on the whole well-balanced, picture of sugar-cane growing in the main producing areas. The chapter on irrigation, however, is much longer than the importance of the subject warrants, while on the other hand, more information on insect pests and diseases should have been included.

The avoidance of highly technical language and a liberal provision of photographs, line drawings and tables, combine to make the book easily understandable to the practical planter, for whom, as the author indicates in his preface, it has been produced primarily, and to whom it can be firmly recommended as providing an answer to most of his problems. For general agricultural students it will be a most useful textbook enabling them to obtain a good overall understanding of sugar-cane production which cannot be obtained from any other single publication.—W.J.B.

MANUAL OF CANE GROWING

By Norman J. King, R. W. Montgomery, C. G. Hughes. *Angus and Robertson, Sydney and London,* 1953. *Pp.* 349. *Illustrated. Price* 63 *shillings.*

This book has been written to satisfy the particular needs of the sugar-cane farmers of Queensland, Australia, but its usefulness is by no means confined to this area.

Literature on sugar-cane growing is mainly published in specialist journals catering for the needs of an industry which operates mainly on factory lines of production. There has therefore been a lack of text-books of this type providing adequate information for the guidance of farmer producers, and a useful text-book for students in general agronomy.

The book is well bound and printed, adequately provided with photographs, tabulated information and diagrams ; the colour plates in the diseases section are particularly good.

As would be expected in a book prepared for use in a specific area, it is lacking in information relative to sugar-cane production in countries other than Australia. This was probably done deliberately because it would have been difficult to know what should be included from other sources and a comprehensive survey would be of little value to small producers. Nevertheless, in reading this book, one is left with the impression that its value could have been greatly enhanced by brief references to some of the more outstanding features of sugar-cane production in areas where conditions are somewhat similar to those of Queensland.

In the section on green manure crops, pages 35–37, the botanical names of the plants mentioned have been omitted except in respect of one crop. This is unfortunate because, for readers outside Australia, the common names are not known. The section on green manuring is obviously intended to indicate that beneficial results follow the use of these crops. There is a considerable amount of information provided concerning the yields of green manure crops and the quantity of nutrients they contain, but a peculiar lack of data relative to any increase in sugar-cane yields following the use of these crops. In the absence of this information, and bearing in mind the results of experiments in other countries, one cannot help but question the wisdom of the advice provided in this section of the book.

There are interesting chapters on mechanical planting and harvesting—a field of development in which Australia has been continuously well advanced —but they have keen rivals in America where numerous machines have been developed during the last decade. Mention of some of the more successful of these could have been included.

In the chapter on chemical weed control, reference is confined to 2, 4–D. This may be wise in a book destined for use by farmers, but it greatly limits

the value of this section to students, who will be expected to have some knowledge of other chemicals in common use as herbicides.

A bibliography would have added considerably to the value of this publication.—W.J.B.

THE YIELDS OF A CROP

By W. Lawrence Balls. *Spon. London.* 1953. *Pp.* xv + 144. 52 *Illustrations. Price* 21 *shillings.*

The cotton crop of Egypt is probably unique, not only in the completeness of Government control of every phase of its production but also in the fact that water control by an elaborate irrigation system is practised during the growth of virtually the whole of the crop.

Playing as it does, a dominant part in the economy of the country, the crop in all its aspects together with the associated problems of irrigation has received the extensive attention of specialist research officers.

During his long association with Egyptian cotton, Dr. Balls has made many valuable contributions towards a fuller understanding of the factors affecting the growth of this important crop, and this, his most recent publication, is probably the most notable of all.

After a brief historical survey of the development of the present day Delta irrigation system, the author proceeds to demonstrate, using official data, that the raising of the river level behind the Delta Barrage has had several consequences over and above the advantages conferred by permitting greater water control for irrigation. Some of these consequences though not immediately obvious, are nonetheless important, and chief amongst these is the effect it has had upon the water table in the Delta. By diagrams and tables he shows that this has risen steadily due to a combination of factors including a permeable soil, the hydrostatic pressure head of the Barrage Pond, seepage from a vast system of unlined irrigation canals, and natural and artificial drainage of water from the irrigated areas.

Having next analysed the factors contributing to the total yield of a cotton crop including crop and cultural improvements, Dr. Balls then discusses the environmental factors which set the limits to this yield. He adduces evidence to show that, aside from the year to year variations of temperature and water availability, pests and diseases, &c., it is this slow but remorseless rise in water table which is ultimately responsible for the downward trends of cotton yields in the country over the past fifty years.

Dr. Balls' summing-up of the present situation is clear and convincing, his forecast for the future gloomy to say the least unless sweeping changes are made in irrigation policy.

This small book is very well produced. The diagrams, liberally used by the author to illustrate his contentions, are excellent even though in many instances they are extremely complex. Complete with a good bibliography and an adequate index anyone even remotely interested in crop physiology will find stimulation in the study of its contents.—J.W.

SOIL STUDIES

STUDIES IN WEST INDIAN SOILS

No. (XII) : The Agricultural and Forest Soils of St. Lucia and
No. (XIII) : The Agricultural Soils of St. Kitts–Nevis, with Notes on Statia (Dutch)

By F. Hardy and G. Rodrigues. *Compiled in January and March*, 1947, *and published in September*, 1953. *Imperial College of Tropical Agriculture, Trinidad. Price 5s. each.*

These two publications belong to a series issued by the Soil Science Department of the College since its inception in 1922. No. (I) (Dominica) and No. (II) (Montserrat) of the series appeared in 1922 in the now defunct West Indian Bulletin. The remainder have retained identical format as these last two under review ; they are usually referred to as " Grey Books ". They comprise No. (III) Tobago, 1931. No. (IV) Grenada, 1932, No. (V) Antigua, 1933, No. (VI) Jamaica, 1933, No. (VII) Trinidad (Montserrat District), 1933, No. (VIII) St. Vincent, 1934, No. (IX) British Honduras, 1935, No. (X) Trinidad (South Central District), 1936, and No. (XI) Montserrat, 1949. They may perhaps best be described as regional studies and are intended to form the basis of reconnaissance soil surveys. The factual material comprising the texts was collected from sources available at the time, but the detail of the actual soil surveys was severely limited by the short periods available during College vacations. Thus it was possible to make within the time available, only cursory road traverses and to examine and sample the main soil-types only in a limited number of profile-pits at sites previously selected by officers of the local departments of agriculture. These restrictions are responsible for the particular selection, scope and arrangement of the relevant information presented in each account. The memoirs were intended to stimulate interest in the agricultural potentialities and limitations of the different territories concerned, and to indicate the urgent need of detailed soil surveys essential for the proper classification of land, the accurate assessment of land capability, the better utilisation of natural resources and the formulation of more satisfactory agricultural systems.

The main outcome of these regional surveys has been the initiation at the College in 1947 of a Soils Research Scheme under the aegis of the Colonial Development and Welfare Organisation. This scheme embraces fundamental studies of the geological relationships, genesis, properties and agricultural features of the main soil-types represented in the British Caribbean Territories. It also includes detailed soil surveys in which the distribution of the soil-types is recorded on suitable maps. For rapid soil mapping, there is urgent need of large-scale aerial photographs such as can actually be taken into the field and

used directly for drawing soil boundaries. So far, most progress has been made along these lines in Jamaica, where two trained soil-surveyors have been working under the scheme since December, 1951. Great help in this work in Jamaica has been afforded by three experienced officers of the United States Bureau of Soils and the Soil Conservation Service, whose services were provided by F.A.O.

Partial soil surveys for special purposes have also been made in British Honduras, British Guiana, Barbados and Grenada, as opportunity and staff permitted, and one is now in progress in St. Vincent.

The profound differences that exist between the agricultural conditions within the various territories, resulting from fundamental differences in geology and topography, are well illustrated by the two areas, St. Lucia and St. Kitts-Nevis, which form the subjects of the two memoirs under review. They are clearly revealed by a cursory glance at the generalized soil-maps appended to each. The most widely-distributed soil in St. Lucia is a " Red Earth " type which occupies the greater part of the central afforested region of the Island, as well as three large valley flats, containing alluvium derived from it, which together comprise about 50 per cent. of the total land surface. This soil-type is not represented in St. Kitts-Nevis, because its characteristic parent material consists of intensely-leached, base-deficient, highly acid, ferruginous-kaolinic residues from deeply-weathered basaltic and andesitic lavas, and has taken an enormous length of time to form. This parent material is not developed in the corresponding parts of St. Kitts-Nevis where the rocks are comparatively young and have been exposed to weathering and soil formation for only a relatively short period. By contrast, about 63 per cent. of the total area of St. Kitts-Nevis is occupied by " Lithosol " and " Yellow Earth ", which consist of fresh or only slightly weathered volcanic " ash " erupted from geologically-recent volcanoes whose craters are still discernible in the mountains.

These form the parent materials of highly productive soils having excellent physical properties and are ranked among the best soils of the Caribbean Region. They are not well represented in St. Lucia, and cover only about 10 per cent. of its total area.

The remainder of the land area of St. Lucia, namely, 40 per cent., is occupied by stiff clay soils, showing greatly impeded drainage. These have been developed over " Terras " and " Shoal " that are geologically very old having been derived from the Miocene basement rocks that form the coastal plains of St. Lucia. These clay soil-types also occur in St. Kitts-Nevis, where they cover 37 per cent. of the total land area, which is about the same as that which they occupy in St. Lucia. Some three-quarters of the St. Kitts-Nevis Shoal and Terras soils occur in Nevis, forming the low-grounds surrounding the central peak. In St. Kitts, they occur almost entirely in the south-eastern (Salt Ponds) promontory which is too dry for profitable arable agriculture. These clay soils are mainly utilised for growing ground provisions

and some cotton, though large areas of them are uncultivated and support a scant xerophytic vegetation.

The essential differences in the kinds and distribution of soil-types in St. Lucia and St. Kitts-Nevis are reflected in their agricultural utilisation. The proportion of uncultivated land, comprising forest or second-growth bush, is about the same in each, namely, 33 per cent. of the total area. The cropping is more diversified in St. Lucia than in St. Kitts-Nevis, though the total acreage under crops is almost the same, namely, 24,000 acres. Food crops occupy about 40 per cent. of the total area in St. Lucia, coconuts 23 per cent., sugar-cane 15 per cent., cacao 13 per cent., citrus 8 per cent. and banana 1 per cent. In St. Kitts-Nevis, sugar-cane occupies 66 per cent. of the total area (mostly in St. Kitts), cotton 19 per cent. and food crops 15 per cent. Coconuts, cacao and citrus are not grown there as commercial crops. The main reason why sugar-cane and cotton figure so prominently in the agricultural products of St. Kitts is because they grow extremely well in the deep porous volcanic ash soil, and because the suitable topography of St. Kitts has permitted the development of a large central sugar factory system, drawing cane from all parts of the Island. Cotton is grown as a " catch-crop " between successive crops of sugar-cane.

There are various other interesting agricultural features of the two contrasted areas which may be explained by fundamental differences in their geology, and these are fully dealt with in the memoirs under review. Much can be learnt from them about the inter-relationships among the five major soil-forming factors, namely, parent rock, climate, vegetation, topography and time, which determined the kinds of soils that have evolved in the Caribbean Region. Thus, in St. Lucia, the time factor seems to have predominated in its effect on soil formation, whereas in St. Kitts-Nevis, the nature of the parent rock seems to have exerted most effect. The two contrasted areas furnish useful material for comparative regional investigations such as form part of the training of the tropical agriculturist.—F. H.

ENTOMOLOGY

UNTAKEN HARVEST

Man's Loss of Crops from Pests, Weed and Disease. An introductory study.

By George Ordish. *London, Constable & Co.*, 1952. *Pp.* xii + 171. *Price* 15 *shillings*

Numerous attempts have been made, especially in Britain and the United States of America, to assess the losses caused by pests, diseases and weeds to agricultural crops. These have usually been expressed as percentage of crop lost or in terms of money value. The author of this book contends that the real loss to a country is not so many thousands of tons destroyed or the millions of pounds they would have been worth, but "the land, the labour and the resources used to grow these ungathered tons". That being so, the title of the book, though arresting, seems scarcely apt, for wasted land and wasted labour cannot strictly be called an "untaken harvest". The objections to estimating losses in terms of percentage of the crop or in money are firstly that the figures of losses to any given crop from various pests are not simply additive. As has been pointed out, if they were, the United States in 1944 grew no wheat or maize at all! Secondly, if they are expressed in terms of money, no account is taken of the fact that, if the losses had not occurred, the price of the commodity would in many cases have fallen. This eventuality has often led to the statement that pests are the friends of the farmer, by keeping up prices and avoiding surpluses, a fallacy effectively disproved by Mr. Ordish.

On the other hand, expressing crop losses in terms of wasted land and labour takes no account of the loss in quality caused by many pests, nor of the fact that a given percentage of loss of a cheap crop is of less importance than the same percentage loss of a valuable crop.

One of the best parts of this book is Chapter 3, on the economic effects of the losses. It is no disparagement to say that this is largely common-sense, for it is common-sense that has not, so far as I know, been said before, and it should be, as the author says "a guide to thinking about this subject". The ratio between the cost of a control measure and the potential benefit derived from it is called the cost/potential benefit ratio. Thus "if the cost is £40 and the potential benefit £120, the ratio is 1 : 3, and if the benefit is equal to the cost, the ratio is 1 : 1. If the benefit is less than the cost, the ratio is $1 : < 1$, and the operation does not pay. It can only be made to pay by reducing the cost of control, or by the relative value of the crop rising." But there certainly can be cases where a control measure that will not pay for itself is a good insurance against the build-up of a pest that is likely to cause serious damage

to future crops. Again, the C/PB ratio does not necessarily give any indication of the relative efficiency of control measures. To take the first item in Table IX, a severe attack by several pests on an apple crop worth £350 per acre, causing a potential loss of £250 p.a. A full control programme is estimated to cost £40 p.a. and to achieve 95 per cent. success. This would prevent a loss of £237 10s. for a sum of £40 in treatment, and the C/PB ratio is 1 : 5.75. The net gain is £197 10s. Partial control at £30 p.a. would give 80 per cent. success, preventing the loss of £200; the ratio is 1 : 6.6 and the net gain £170. Low control at £12 p.a. would give 65 per cent. success, preventing the loss of £162 10s. ; the ratio is 1 : 13.6, but the net gain only £150 10s. In this case it is clear that it would pay the grower to adopt the full programme, although its C/PB ratio is less than half that of the low programme. The C/PB ratio certainly gives an indication of the per cent. return to be expected on the money invested in a control operation. Would it not, however, be of more value to the farmer to calculate the extent to which losses would be reduced by expressing the estimated results of a control programme as a percentage of the potential loss ? This might perhaps be called the 'Effective Ratio' and would work out in the example quoted above, as 100 : 79 for a full programme; 100 : 68 for a partial programme; 100 : 60.2 for a low programme. To take another example from Table IX, that of a potato crop valued at £75 p.a. subject to a slight attack by blight and virus estimated to cause a potential loss of £8. A full control programme shows a C/PB ratio of 1 : 0.95 and E.R. of 100 : —5, i.e., both indicate a 5 per cent. loss. A half control programme shows 1 : 1.8 and 100 : 40 and a low control programme 1 : 4.5 and 100 : 66 respectively. This is a case where a lesser degree of control, because of its higher C/PB ratio, does give more economical results.

Chapter 4, dealing with the methods of combating the loss and the economics of the methods, is also of great interest. Some of the examples quoted, where research projects have yielded an annual return of many hundreds or even thousands, per cent. of the initial outlay, should be framed and hung in the offices of all those responsible for allocating funds for research.

The author might, it is felt, have given some advice on calculating the prospective benefit to be derived from a control operation. This is not simply the estimated value of the crop saved minus the cost of the operation: other factors, such as the cost of harvesting, storing and transporting the increased crop often have to be taken into account. This is a complicated subject which of course varies with the crop and the nature of the damage. For instance it costs just as much to harvest, and extract the reduced quantity of sugar from cane riddled with borer as it does from sound sugar cane. But if, in a field of cotton, 20 per cent. of the plants have been killed at an early age by flea beetle, one is at least saved the cost of picking the cotton from the non-existent plants.

Chapter 5 deals with the social effects of agricultural pests. How many people realise, for instance, that Britain's addiction to tea-drinking was caused by a microscopical rust fungus on coffee in Ceylon?

If there are some statements with which not everyone will agree, and some aspects of the subject which could have been treated more fully, this is nevertheless a stimulating book and one that, for once, justifies the cliché that "it fulfills a long-felt want".—T.W.K.

LIST OF SUGAR-CANE INSECTS

A synonymic Catalogue of the Sugar-cane Insects and Mites of the World, and of their Insect Parasites and Predators, arranged systematically.

By Harold E. Box, *Commonwealth Institute of Entomology, London*, 1953. *Pp.* 101. *Price* 15 *shillings.*

This publication, being just what it sets out to be, is scarcely susceptible to review. It appears to have been carefully compiled and it will be of value to anyone working on the entomology of sugar-cane. Several references in Zimmerman's "Insects of Hawaii" appear, however, to have been overlooked. It is understood that the unnecessary commas inserted after each specific name are an error of the printers, not of the author or the publishers. It seems desirable to call attention here to the modern nomenclature of a few common cane insects. The sugar-cane aphid, *sacchari* Zhnt., has been transferred to the genus *Longiunguis*. The maize aphid, *maidis* Fitch (one of the vectors of sugar-cane mosaic) is now referred to the genus *Rhopalosiphum*. The unwieldy genus of mealybugs, *Pseudococcus*, has recently been split up by G. F. Ferris : of the mealybugs recorded from sugar-cane, *boninsis* Kuw. and *brevipes* Ckll. are now referred to *Dysmicoccus*, and *sacchari* Ckll. to *Saccharicoccus*. Mr. Box has not, however, followed Ferris in referring *citri* Risso to the genus *Planococcus*. The South American locust, long known as *Schistocerca paranensis* Burm., is now *S. cancellata* Serv.—T.W.K.

THE SOCIAL INSECTS

By O. W. Richards. *Macdonald, London* 1953. *Pp.* 219. 51 *photographs. Price* 15 *shillings.*

Many books have been written on the fascinating subject of the social insects —the termites, ants, bees and wasps—but there was certainly a need for an up-to-date one such as this, if only to include the recent remarkable discoveries of von Frisch on the language of bees and the original observations of Dr. Richards himself (and his wife) on tropical wasps in British Guiana.

Stress is rightly laid on the profound differences rather than the superficial resemblances between insect and human societies, and Dr. Richards has most successfully avoided both the Scylla of anthropomorphism and the

Charybdis of technicalities, without either detracting from the interest and readability of the book or any sacrifice of scientific accuracy.

The phenomenon of trophallaxis, or the mutual exchange of food between the adult workers and larvae of social insects, is perhaps rather inadequately dealt with. Trophallaxis is practised by all the social insects except the bees, though the larval secretions so eagerly devoured by the workers are of several different sorts. It is usually supposed that it plays an essential part in initiating and maintaining the apparent solicitude shown by the workers for the larvae, but Dr. Richards is of the opinion that there is little evidence for this and that it may be of more importance as a sanitation measure.

The photographs are of a high standard, there is a short list of suggestions for further reading and an adequate index.—T.W.K.

MISCELLANEOUS REVIEWS

WELTATLAS

Die Staaten der Erde und ihre Wirtschaft

Veb. Bibliographisches Institut Leipzig, 1952. 97 *maps* + 63 *pp.* *Price* 18 DM.

The principal function of this publication is to map the world distribution of industry and agriculture. Each political map, printed on the left hand page, is faced by a map on the same scale on the right, showing the location of industries by means of symbols. Back reference to the key is avoided by supplying a duplicate key printed on a separate sheet. The result is complex but detailed, and amply fulfils the objects of the publishers.

The use of abbreviations for the names of towns on the industrial maps is irritating and unnecessary. The admirable 1:1,400,000 mapping of Germany could with advantage have been extended to industrial areas of other countries, as on the smaller scale maps, these areas are covered by an almost unreadable hotch-potch of letters and symbols. This trouble is aggravated to a certain extent by the heavy shading adopted to denote coal-bearing areas.

The " Weltatlas " is a useful supplement to the more general publications of this type. It is suggested that later editions might be greatly improved by including a certain amount of economic information in diagrammatic form ; it would be of great utility, for example, if each industrial map were accompanied by diagrams showing the relative importance of the major industries of the area. The index could be usefully expanded to give a little more information than the bare map reference to each place-name.

The maps are well printed on good paper ; the choice of paper for the index is unfortunate, and spoils the appearance of the book.—K.W.D.

FARM MECHANIZATION HANDBOOK

By T. Hammond Cradock. 2nd Edition. *Temple Press Ltd., London* 1952. *Pp.* xxix + 339. *Illustrated. Price* 10*s.* 6*d.*

This book assumes a minimum of experience in the reader but nevertheless provides a logical and practical guide to the diagnosis and treatment of mechanical faults in tractors, ploughs, mowers, combine harvesters and pick-up balers.

The author is essentially practical in his approach to the subject and carefully discriminates between repairs which can reasonably be undertaken on the farm with relatively simple tools and those which demand special equipment. The detailed instructions given should provide the timid with sufficient confidence to undertake repairs which might normally be considered beyond the scope of the farm workshop, while the foolhardy should benefit greatly from equally explicit instructions regarding those repairs which should be dealt with by a specialist.

The section on workshop and equipment usage is rather sketchy in comparison with the rest of the volume but the inclusion of line drawings of the most popular British tractors accompanied by repair information regarding running clearances of bearings, &c., is both novel and commendable.

This is a book of value to all interested in using and maintaining agricultural equipment at a high level of efficiency. It will prove of particular value to those whose duties take them far from highly organised workshops and repair services.—P.H.R.

SCIENCE AND FRUIT

Edited By Professor T. Wallace & R. W. Marsh. *University of Bristol* 1953. *Pp.* xiii + 308. *Illustrated. Price* 30 *shillings.* ($4.50 U.S.)

The year 1953 is the jubilee of the Long Ashton Research Station, and in this Commemoration Volume the history and progress of this now justly world-famed institution is traced from its small beginnings as an institute for research and instruction on cider making and fruit growing in 1903, to its present status as one of the main research centres in the organization of the Agricultural Research Council.

With a foreword by the Rt. Hon. Sir Winston Churchill, Chancellor of the University of Bristol, with which the institute has been associated since 1912, Lord Rothschild's Jubilee Lecture, and a preface by Capt. D. M. Wills, the main text of the volume, divisible broadly into two parts, is a series of reviews by various authors.

One set of these contributions provides a general survey of the work done at the Station between 1903 and 1953 and includes an excellent account of the foundation and development of the cider-making industry as we know it today and which owes so much to this Institute. The other set of contributions reviews the progress made in a wide field of specialist investigations covering various aspects of fruit culture, plant nutrition, plant pathology and fruit preservation. The volume concludes with an interesting record of research staff and other officers associated with the Institute since its inception.

While obviously this book is to be regarded as a record of achievement rather than a work of reference, the addition of an index would have been useful.

The production is magnificent and entirely befitting to the occasion celebrated.—J.W.

BIBLIOGRAPHY ON THE GENETICS OF DROSOPHILA

By Irwin H. Herskowitz. Part II *Bibliography No. 6 of the Commonwealth Bureau of Animal Breeding and Genetics, Edinburgh. C.A.B., Farnham Royal, Slough, Bucks. Pp.* xi + 212. *Price* 21 *shillings* ($3 U.S.)

Fourteen years have passed since the publication of Professor Muller's Bibliography on the Genetics of Drosophila. (Imp. Bur. An. Br. Gen. **5**, 1939). In it were listed 2,965 papers which had been published during the preceding 15 years. The present Bibliography is designed as a supplement to Professor Muller's. It contains 2,841 references and covers the period 1939–50 inclusive. A title index to both bibliographies is given and will undoubtedly prove useful.

Geneticists—and many other biologists too—will be grateful to Dr. Herskowitz for his painstaking work of compilation and to the Commonwealth Bureau for satisfactory printing and layout. The reviewer noticed only one mistake (though he has admittedly not read the whole book)—reference 2730 should presumably read "Whiting" rather than "Whitting". But a guinea seems expensive for paper covers and two hundred odd pages of poor quality paper.—N.W.S.

COMMUNICATIONS ON ORIGINAL INVESTIGATIONS

THE USE OF POT TESTS IN RESEARCH ON THE FERTILITY OF SUGAR-CANE SOILS

BY

H. SCHROO

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Paper I. General Principles and Technique of Pot Tests, with Special Reference to Cane

General Principles

Pot Tests provide a means of obtaining direct and accurate information concerning certain fertility problems that cannot be so easily, quickly or cheaply obtained by field experiments. It is essential however, that in order to avoid misinterpretation of the results obtained, the limitations of the technique are thoroughly understood and the method is not applied to unsuitable projects.

A particularly advantageous feature of pot tests is the elimination of variations in soil fertility such as are normally encountered from plot to plot in any field experiment. This is achieved by a thorough pulverizing, sifting and mixing of the batch of soil to be used in the test, thereby levelling off inherent variations. The structure, moisture content and drainage of the soil in each separate container are then carefully standardized, and further external growth factors such as watering, degree of insolation and of exposure to wind, are also equalized as much as possible. The compactness of a pot test, as compared with a field experiment, greatly favours the proper control of these external factors and ensures the accuracy of the test, since hazards which may spoil the work of many months are practically eliminated.

The equipment involved is quite simple and inexpensive and a single test can provide the agronomist with rapid and valuable information as a basis for further field experimental work and can be conducted on any estate within a short space of time and at low cost.

In testing the soil and in attempting to solve problems of plant nutrition, either a small quick-growing indicator plant can be used, or sugar-cane itself can be grown for a shorter or longer period, depending on the particular needs of the test. In both cases the test plant is used to extract plant nutrients from the soil, and comparative growth rates, yields, or nutrient uptake from treated and untreated portions of soil are taken as an index of the nutrient status.

The well-known indicator plant technique, originally proposed by Mitscherlich and afterwards modified by various investigators, is of strictly limited value in providing practical information about the nutritional requirements of tropical crops in general and of sugar-cane in particular. The assumption on which this method is based, i.e., that all plants will react under all conditions in the same way and to the same extent to a given nutritional factor or set of factors, is unfortunately inaccurate. Consequently there is no simple means of translating the results obtained from indicator plants into nutritional needs or fertilizer responses of cane grown on similar soil in the field. The best we can hope for is to find a certain correlation between the demands of the indicator plant and those of the cane under the standardized conditions of the experiment. The more the plants show a relationship in the way they react to ecological factors, the more likely is it that a correlation can be established.

Another serious difficulty in the use of the indicator plant method under tropical conditions is the great difference in soil volume occupied by various root systems, and the varying duration of vegetative plant-growth. Therefore most of the suitable indicator plants, such as small grains or vegetable crops, require a higher nutritional status of the soil than large plants such as cane, because of their limited rooting area and short growth period. In most cases, therefore, the use of an indicator plant is justified only in purely comparative investigations of "single value" factors, in which circumstances the indicator plant is used merely as an arbitrarily chosen "measuring stick" and is as good or as bad as any other conventional laboratory testing method.

Testing sugar-cane soils with the aid of sugar-cane itself can certainly be considered as an improvement over the indicator plant method, as it is more likely that the pot test results will be indicative of what can be expected in the field. Nevertheless, it should still be borne in mind that the conclusions drawn from the test are of a more qualitative than quantitative character, and therefore one should not attempt to base quantitative field recommendations on the outcome of the test. By restricting the technique to the qualitative study of interrelations between soils, fertilizers and cane varieties, direct and valuable information may often be obtained on problems which otherwise would have to be solved by means of expensive and time consuming field experiments. Particularly when chemical soil analysis is lacking or inadequate as a basis for field experimental work, it is extremely difficult to obtain a clear picture of a regional soil fertility problem from the manifold and often contradictory data obtained from field trials. In such a case an extensive preliminary study with the aid of well designed pot tests will often reveal the fundamentals of the problem more clearly. Finally it should be noted that the equipment proposed below is kept as simple as possible in order to make the technique applicable to average estate conditions in the tropics. The technique may also be used for other small and medium-sized tropical crops, provided that the shape and size of the container is adjusted to the specific needs of the root system, and it is especially useful when new enterprises or pilot schemes are involved and rapid basic information is needed.

Types of Pot Tests

Pot tests with sugar-cane may be divided into three types according to the experimental aim and the kind of container available. In subsequent papers, examples of each type of pot test will be presented so as to illustrate the underlying principle of each.

The first two types are designed to investigate the nutrient status or other properties of the soil as measured by the response of a given cane variety to various treatments. Depending on the period of growth, the volume of the container should be such as to avoid deficiencies which might arise when too limited an amount of soil is used. The tests are run in the open and no precautions are taken to prevent loss of nutrients, other than the provision of a water-trap with overflow at the bottom of the container to reduce the rate of leaching. The nutrients not under investigation are supplied at regular intervals in amounts sufficient to level off variations in leaching from pot to pot.

In the third type of cane pot test, the cane plant is used as a soil-exhauster for the purpose of gauging the relative value of a "single factor" such as the potash status of various fields within a given soil area. The available volume of soil is very much restricted in order to hasten the effects and accentuate the inherent differences of the treatments. When dealing with a factor which is subject to leaching, it will be necessary to collect all drainage water and to return it to the soil surface in the container as is done in Mitscherlich tests.

Type 1. In pot tests of Type 1, only the *early* response of cane is studied and the cane is grown for only four months in containers made of double kerosene tins which together measure 8 gallons and which hold about 65–75 lb. of air-dry soil. (Plates 1, 2b and 3). The great advantage of the short duration of this test is that three or four subsequent tests can be run in the same time as would be required for only one field-trial of the same statistical type. A few points should be remembered when considering the results of this test :

(*a*) Factors which affect the early tillering and growth do not necessarily extend their influence to later stages, but it is assumed that treatments and treatment levels giving promising responses in four months old cane are worthy of further trial in the field, whereas treatments which give no significant response at that stage of growth may be ruled out in further investigations.

(*b*) The cane variety should be chosen with care. Cane varieties may differ greatly in their reaction to soil conditions and in their response to fertilizers, though these varietal differences are small during the first three months and become more pronounced with age.

(*c*) Growth factors, other than those under investigation, are maintained at an optimum level in the test. Under field conditions, however, control of factors such as climate, soil structure and surface wash of fertilized top-soil layers, may be impossible. This does not reduce the validity and importance of the pot test results but merely presents a secondary problem in their application.

Type 2. In pot tests of Type 2, sugar-cane is grown for a longer period so that early responses can be followed up to maturity. Forty-gallon oil-drums are used holding about 300 lb. of air-dried soil, sufficient to support two complete cane stools yielding up to 30 lb. of millable cane. (Plates 4, 5 and 6). The method lacks the advantage of giving information more quickly than a field trial, but the accurate control possible will prove an advantage for several experimental objects, especially when from factory considerations an interest is taken in the relation of juice and cane qualities to field treatments. This point will be discussed in a later paper.

Type 3. In the third type of pot test which is only used for comparative purposes, sugar-cane is grown for three months in a single kerosene tin (Plate 2a), containing 32–36 lb. of air-dry soil. Moisture and nutrient supply have to be more closely adjusted especially towards the end of the experiment, when the vigorously growing cane draws heavily on the relatively small amount of soil and limited amount of available water in the container.

Finally it should be noted that additional information of considerable value may be obtained if adequate laboratory facilities allow of leaf or plant analysis, so that treatment responses may be studied in relation to plant metabolism.

Technical Notes

1. *Soil-sampling:* Since soil fertility may vary greatly within a given soil type, soil phase or field, the method and site of sampling should be carefully planned and adapted to the particular aims of the experiment. In general, a large sampling area should be avoided since the levelling of extremes within the area is too great. It is the poor and failing spots in a field which represent the true fertility problem in that area and which eventually justify the use of a fertilizer in order to increase the average yield.

This is particularly true when erosion phases, texture phases or drainage phases alternate within an area. Therefore it is better to keep the extremes separate in pot tests of Types 1 and 2, rather than use an "average" sample by mixing the extremes together. Once the sample area is chosen and the sample depth is defined, the more sub-samples taken from all over the area the better. If sampling is confined to the shallow top-soil layer, it should be remembered that certain nutrients may have accumulated there whereas others may be lacking, having been washed down into deeper layers. The time of sampling is also important owing to the possibility of salts concentrating in the upper layers of arid soils during dry seasons.

The total amount of soil needed to complete a full series of experiments should be collected at one sampling. The whole batch of soil should then be pulverized and passed through a $\frac{1}{2}$-inch sieve. As each soil type will have a specific moisture content at which this disintegration can be done most easily, air-drying or slight moistening may have to precede this process. The air-dried, finely-divided soil is thoroughly mixed by repeatedly dividing the batch into a number of smaller heaps and then uniting them shovelful by shovelful. After this, the soil can be stored until required.

PLATE 1—Double kerosene tin showing 4 months old cane.

(*a*) (*b*)

PLATE 2—Single and double kerosene tin containers.

PLATE 3—Layout of an experiment of Type 1.

PLATE 4—Forty-gallon drum showing crumb structure of soil and seed piece in position.

PLATE 5—Drums with 8 months old cane.

PLATE 6—Layout of an experiment of Type 2.

2. *Containers:* All containers should be double-coated inside with bitumastic paint and outside with white paint. When using kerosene tins in tests of Types 1 and 3, a loose platform made of $\frac{1}{4}$-inch square wire-netting is fitted inside each tin, two inches above the bottom. This is covered with kraft paper before the soil is filled in. This platform is the actual bottom of the soil-column and underneath there is sufficient space for drainage water to collect. In dry spells this space may be filled with sub-irrigation water. Two glass-tubes reach down through the soil into this reservoir and facilitate its filling and the escape of air. A narrower tube with a right-angle bend is fitted into one side of the tin near the base. This acts as a gauge and also as an overflow when the reservoir is entirely filled (Plate 2). As long as the water in the reservoir when full is just in contact with the base of the soil-column, the soil will not dry out and shrink away from the wall of the container during dry weather, nor will water-logged conditions, resulting in root-rot, occur after heavy showers. The double tin consists of two single tins soldered together with most of the partition wall removed. A loose partition wall can be inserted to separate the two halves again, when using the container as a split-plot in Type 3 tests. Thus, the split-plots have their water-table in common and, for example, a lime against no lime treatment may be allocated to each half. The container should be placed in such a way that the water table is level.

In the large oil-drum containers no attempt is made to create a water reservoir underneath the heavy soil filling. A four-inch layer of very coarse gravel is placed in the bottom of each drum with a layer of fine gravel on top. A 2-inch drain-hole is made in the drum wall near the base. During the dry season, however, it might be better to raise this drain-hole for some four inches above the base so as to provide some water holding space. In this case, the nature of the gravel should be considered in relation to the treatments included in the experiment.

3. *The Experimental layout* (Plates 3 and 6): These types of pot tests should be run as factorial experiments so that a valid analysis of variance may be attempted. Treatments should preferably be replicated three times and the experiment planned in such a way that an error variance based on more than ten degrees of freedom is obtained. While complexity is no drawback in a well designed experiment, until the fundamental reactions of the plant to a simple combination of factors are fully understood, initial complexity should be avoided.

If the containers are spaced widely enough to ensure that each will receive the maximum amount of sunlight, guardrows are unnecessary. Wind may prove a hazard however and therefore a sheltered site will be most suitable.

4. *Filling the containers:* Before filling, the soil should be brought to a moisture content somewhat below the sticky point. The soil aggregates so formed will last indefinitely. Since, with different soil types, the proportions

of air-dry soil and water required will differ, these should be ascertained beforehand. The amount of soil required to fill one container is then weighed and spread on a tray or concrete floor and the exact amount of rainwater is measured into a watering can. Soluble fertilizers to be added, except those which are to be " placed ", are dissolved in the water. The solution is added gradually from the watering can to the soil and is thoroughly mixed in until the desired aggregate structure is obtained. Where lime is to be applied, it should be mixed thoroughly with the dry soil before moistening. Before containers are put in place on the ground, insecticide powder should be sprinkled liberally underneath to keep ants away.

5. *Planting the Sugar-cane:* Usually single-eye seed-pieces taken from the first or second eye at the top of the cane stem are used for the pot tests. When planting the smaller containers, it is preferable to pre-germinate in layers of quartz sand a larger number of cuttings than is strictly required. After 10 to 14 days, the cuttings are carefully removed, washed in water and the required number, showing a similar degree of germination, is selected. If the total number of equally developed cuttings available is insufficient, at least each statistical unit (block or replicate) should be planted with uniform seedlings.

In the big drums two stools may be developed and it will normally suffice to plant 3 setts (usually 3 consecutive eyes of one cane top) later retaining the two most uniformly germinated and discarding the other. Normally there will be little difference in shoot-development during the first two weeks after planting, so that all differences in development which show up later are due to differences in treatment.

It is essential that the depth of planting should be uniform, since the shallower the cutting is planted the more it tends to tiller. Under dry-season conditions, shallow planted cuttings in particular tend to sprawl.

6. *Growth and reaping:* Length measurements and tiller counts should be made at intervals during growth. Shoot length is taken as the distance from seed piece level to the last visible "dewlap " (collar mark). Both tiller count and total shoot length per container are used in the statistical analysis of the results, although their relative importance may vary with the type of treatment. The fresh weight of the aerial aparts reaped is the best variant to use in the final analysis of the experiment.

Leaf-analysis, carried out at intervals during the experiment, may provide useful supplementary information about metabolic changes accompanying growth. This procedure should be standardized in order to obtain comparable data within each experiment. Generally the third leaf from the top, with visible " dewlap ", is collected from each of the two first developed shoots in each container. The leaf is cut off at its base, the top half removed, the midrib discarded and the lamina is dried and ground for further analysis. In considering the results of leaf analyses, the relative treatment values are of

more importance than the absolute values. Cane grown to maturity in the large drums is trashed at intervals and the trash is cut up into small pieces and applied over the soil around the stool. The stools and foliage should be dusted regularly with insecticide powder.

On no account should the soil be allowed to dry out, as it will shrink from the drum wall and subsequent watering will be ineffective, causing erratic results. When reaping the cane, the stalks are cut off at seed piece level, the final length of each is measured and the total fresh weight taken. Mature canes in large drums are cut off in the same way, topped, trashed and weighed for millable cane. This cane is subsequently milled, the juice weighed and juice samples are taken for further analysis in the laboratory.

THE USE OF POT TESTS IN RESEARCH ON THE FERTILITY OF SUGAR-CANE SOILS

BY

H. SCHROO

Paper II: A pot test with potash, lime and magnesia on the early response of cane grown on Talparo Red Clay

Introduction

The pot test was conducted with a large sample of "Talparo Red Clay" collected from Hermitage Estate (Field 43) belonging to the Ste. Madeleine Sugar Company, Trinidad. This soil is related to Tropical Red Podzol, and is a much leached, highly acid, non-calcareous, base-deficient clay, covering about 104,000 acres in two broad belts on either side of the Central Range in Trinidad. The analytical data are given in Table I. A full description and discussion of this soil-type is given elsewhere (Hardy, 1941).

The Talparo Red Clay, though inherently not a potash-deficient soil, generally shows values for available (i.e., exchangeable) potash ranging from medium-low to medium-high. The sample used gave a medium-high value.

Field trials with cane carried out in the past on this soil-type and summarized by Hanschell (1951), showed that part of the red-soil area has a potash status verging on shortage which curtails full response to other fertilizers, especially by ratoon-crops. Sugar-cane is a great consumer of potash with a demand upon the soil for this nutrient which may run to well over 800 lbs. of K_2O per acre.

No potash fertilizers are used in this sugar area, and, apart from burning the cane before reaping, all potash contained in the millable cane is removed from the field and never returned. Taking an average figure from various investigators as quoted by Dillewijn (1952, Table 65), it might be assumed that each ton of millable cane removes 2½ lbs. of K_2O. This means that an average crop of 40 tons of plant cane followed by three ratoons yielding together 100 tons of cane, will remove an equivalent of 5 cwts. of muriate of potash from an acre. In addition to this continuous loss of potash, the potash-fixing properties of the soil seated in the illite part of the clay-fraction, may restrict the availability of the potential potash resources of the soil.

Table 1

Silt & Clay %	Index of Texture	Reaction		Org. matt. %	Total N. %	C/N ratio	Electr. cond. mhos x 10-6		P_2O_5		K_2O
		norm. pH	exch. pH				Av. Nutr.	Rate of Solution	Tot. ppm.	Avail. ppm.	Avail. ppm.
99	49	4.6	3.9	2.2	0.15	8.7	80	10	850	18	249

Furthermore, the highly acid soil reaction also may induce a stronger binding of the potash at the surface of the predominant kaolinitic clay-fraction (Russell, 1950). In order to gauge the potash status of the soil in question, an accurate test was designed to measure the response of sugar-cane to potash fertilizer after four months' growth, on the assumption that responses obtained at that age are also likely to be obtained at later stages of growth. In this experiment the potash treatment was combined with a lime* and a magnesia treatment. The absorption of potassium by roots is governed by the absorption of other ions, particularly calcium and magnesium, and the design of this experiment gives an opportunity to study the interactions between these three cations.

Calcium as a plant-nutrient is not lacking in this gypseous soil-type although it is not in circulation as an exchangeable cation. The particular reason for including lime in the experiment was the high acidity of the soil. Talparo clay is known to have the highest lime requirement of all Trinidad soils and its nature is that of an " aluminium clay," in which aluminium acts as an exchangeable base, rendering the soil toxic to the roots of many plants. It was found that indicator plants like tomatoes, Sudan grass and maize, could not be grown in this acid medium. Their root systems invariably showed the symptoms of aluminium toxicity described by McGeorge (1925). Only maize with the aid of considerable phosphate dressings could withstand the toxicity, but, with a minimum amendment of $4\frac{1}{2}$ grams of calcium carbonate per kilogram of air-dry soil, all plants could be grown even without the help of phosphate. Although sugar-cane is hardier and more tolerant to these particular acid soil conditions, the same stubby knotted root development was noticed in the field during the early stages of growth, indicating the necessity of liming to ensure proper root functioning and better utilisation of nutrients, in addition to general soil rehabilitation.

The effect of liming is studied in its various aspects in this experiment.

Magnesia was included in the test because previous pot tests with maize on this soil-type had shown beneficial results from magnesia in combination with lime, whereas in other tests magnesia applied without lime depressed the yield. This particular soil-type is not generally regarded as magnesium-deficient, but it still seemed of interest to include magnesia, together with potash and lime and to study their mutual relationships as indicated by yields and nutrient uptake of the cane plants. A liberal dressing of phosphate and nitrogen was applied to all treatments.

Methods

(*a*) *Outline of the pot test.* Double tin containers of the type described in the previous paper were used. The amount of air-dry soil used per container was 30 kilograms (66 lbs.), and the root room in the container was $1\frac{1}{2}$ sq. ft. area with 1 ft. depth. Each of the three factors, potash, lime and magnesia,

*Throughout this article the term lime denotes calcium carbonate

was tested at two levels, zero (K_0, L_0 and M_0) and ;

K_1—25 grams potassium chloride per container (=2 cwts. KCl per acre of 4,000 plants)

L_1—300 grams calcium carbonate per container (=8.7 tons per acre of 4,000 plants)

M_1—3.5 grams $MgSO_4.7H_2O$ per container.

The lime was mixed with the whole volume of soil before moistening. The amount used (10 grams calcium carbonate per kilogram) is equivalent to three times the theoretical lime requirement that would bring the reaction of the soil to about pH 6.5. To counteract leaching, the potassium and magnesium salts were dissolved in the water used for moistening the upper, but not the lower, six inches of soil. The fertilizer dressings used in all treatments were :—

37.5 grams of 40 per cent. superphosphate per container, applied in powder form to top 6 inches.

50 grams ammonium sulphate applied in two dressings of 25 grams at planting and 25 grams after three months.

The 2x2x2 different treatment combinations were replicated in three randomized blocks. The plants were reaped four months after planting. Cane seed pieces, of the variety B37–172, were collected at Ste. Madeleine on 30th September, 1952, pre-germinated in quartz sand and transplanted, after selection, on 10th October. Rainwater only was used for watering. The cane was reaped on 3rd February, 1953. Shoots were cut off at seed piece level, the number of shoots with a length greater than 9 cm was counted, the total length of all shoots was measured, and the total fresh weights of all shoots per container were taken immediately after reaping. All measurements were completed for one container before proceeding to the next, completing successive blocks in this way.

In Table 2 the experimental results are given for " fresh weights," " total lengths " and " tiller count," and in Table 3 statistical analyses of results are presented.

(*b*) *Leaf analysis.* Immediately before reaping, leaf samples were taken from each container for leaf-tissue analysis. The uppermost leaf showing a " dewlap " (collar mark) was taken from the two tallest (i.e. first developed) shoots in each container. The top halves were discarded and the midribs were stripped and the remaining laminae dried. After drying, the treatment-triplicates were combined and each bulk sample was finely ground, mixed and oven-dried. A sub-sample of 1 gram of powdered, oven-dried material was extracted for half-an-hour with 100 c.c. of 2 per cent. acetic acid, shaking by hand every ten minutes. After filtering, the extract was analysed for phosphate, potassium, calcium and magnesium, which are expressed as milligrams per litre extract (p.p.m.) in Table 4.

TABLE 2 *Yield Data expressed as Fresh Weight, Total length and Tiller Count*

FRESH WEIGHT (SHOOTS) in kilograms

	Triplicates			Totals
0	1.77	1.97	1.72	5.46
M	1.79	1.68	1.58	5.05
L	2.36	2.24	2.14	6.74
K	2.22	2.44	2.01	6.67
ML	2.03	1.85	1.89	5.77
MK	2.37	2.27	2.16	6.80
KL	2.29	2.55	2.15	6.99
LMK	1.97	2.37	2.22	6.56
Total	16.80	17.37	15.87	50.04

THREE-WAY TABLE

	No Lime			Lime			Totals	No Mg	Mg
	0	Mg	Tot.	0	Mg	Tot.			
0	5.46	5.05	10.51	6.74	5.77	12.51	23.03= **100%**	12.20	10.82
K	6.67	6.80	13.47	6.99	6.56	13.55	27.02= **117%**	13.66	13.36
	12.13	11.85	23.98	13.73	12.33	26.06	50.04	25.86	24.18
			100%			**109%**		**100%**	**94%**

TOTAL LENGTHS (SHOOTS) in metres

	Triplicates			Totals
0	5.53	6.34	5.57	17.44
M	6.78	7.92	5.46	20.16
L	7.16	7.46	7.15	21.77
K	7.43	7.42	7.11	21.96
ML	7.70	6.94	5.90	20.54
MK	6.88	7.53	8.10	22.51
KL	8.75	7.07	7.03	22.85
LMK	7.78	7.47	7.67	22.92
Total	58.01	58.15	54.00	170.15

THREE-WAY TABLE

	No Lime			Lime			Totals	No Mg	Mg
	0	Mg	Tot.	0	Mg	Tot.			
0	17.4	20.2	37.6	21.8	20.5	42.3	79.9= **100%**	39.2	40.7
K	22.0	22.5	44.5	22.9	22.9	45.8	90.3= **113%**	44.9	45.4
	39.4	42.7	82.1	44.7	43.4	88.1	170.2	84.1	86.1
			100%			**107%**		**100%**	**102%**

TILLER COUNT

	Triplicates			Totals
0	13	14	13	40
M	18	23	14	55
L	17	18	17	52
K	21	16	17	54
ML	21	18	13	52
MK	16	20	20	56
KL	22	15	18	55
LMK	23	18	17	58
Total	151	142	129	422

THREE-WAY TABLE

	No Lime			Lime			Totals	No Mg	Mg
	0	Mg	Tot.	0	Mg.	Tot.			
0	40	55	95	52	52	104	199= **100%**	92	107
K	54	56	110	55	58	113	223= **112%**	109	114
	94	111	205	107	110	217	422	201	221
			100%			**106%**		**100%**	**110%**

TABLE 3 *Statistical Analyses*

	D.F.	Fresh weights		Total lengths		Tillercount	
		MS.	F	MS.	F	MS.	F
Blocks	2	71.6	4.27*	26.6	5.70 *	15.3	—
K	1	666.7	39.80**	45.1	9.72**	24.0	2.95
L	1	180.3	10.76**	15.0	3.2	6	—
M	1	117.6	−7.02*	1.7	—	17	2.1
KL	1	153.5	9.16**	4.8	—	2	—
KM	1	48.6	—	0.4	—	4	—
ML	1	52.2	—	8.8	—	8	—
LMK	1	0.1	—	5.4	—	10	—
ERROR	14	16.75		4.64		8.14	

P=0.05*
P=0.01**

TABLE 4. *Leaf Analysis*

	Phosphate (P_2O_5) p.p.m.	Potassium (K_2O) p.p.m.	Calcium (CaO) p.p.m.	Magnesium (MgO) p.p.m.
0	30	200	53	25
K	26	**243**	43	21
L	**62**	206	**57**	**29**
M	31	190	50	25
KL	**48**	**254**	42	25
KM	28	**218**	43	21
LM	**63**	209	48	**27**
LMK	**53**	**270**	47	21

TABLE 5. *Plant Analysis*

	Nitrogen (N)		Phosphate (P_2O_5)		Potassium (K_2O)		Iron ($Fe^{\cdots}$)	
	grams	index	grams	index	grams	index	mgr.	index
0	5.94	100	1.44	100	7.66	100	10.26	100
K	7.10	119	1.89	131	15.53	203	27.63	270
L	6.42	108	3.52	244	10.20	133	18.69	182
M	4.02	67	1.07	74	5.45	71	8.14	79
KL	6.04	102	3.02	210	17.05	223	38.57	375
KM	5.79	97	1.70	118	13.67	178	21.36	208
LM	4.37	73	2.21	153	6.22	81	22.77	221
LMK	5.54	93	3.00	208	14.24	186	31.92	311

(c) *Plant analysis.* The total dry matter per container, derived from the complete shoots, was weighed, pulverized in a hammer-mill and sub-sampled, and the nitrogen, phosphate, potash and iron contents were determined. The percentages found for each constituent were multiplied by the total dry weight of the crop, and these " total-uptake " figures are presented in Table 5.

Conclusions

(a) *Yield figures* : (Tables 2 and 3).

(i) Fresh weights. The potash treatment was highly significant (P=0.01) and dominated all other treatments, causing an overall increase in weight of 17 per cent. The lime treatment was also highly significant, causing an overall increase in weight of 9 per cent.

Magnesia exerted a significantly depressing influence. Leaves of magnesium-treated plants had a peculiar bright green colour, and the general form of the plants was slightly stunted and bushy. Dividing the shoots into tops plus leaves and stripped stems, the weights of the first and second are in the ratio of two to three. Each of them showed the same percentage response to treatments as was found for their total fresh weights. There was also a highly significant interaction between potash and lime treatments ; the beneficial influences of both treatments were not cumulative.

(ii) Total length and tiller count. The analysis of variance for total shoot length shows that only the potash treatment was highly significant. In the analysis of tiller counts none of the treatments was significant. This was mainly due to the comparatively high value of the error variance. The variation in small shoots from stool to stool makes the tiller count a less accurate gauge for the effects of these particular treatments. From Table 6 it can be seen that the potash and lime treatments hardly affect the average length so that the increases in total length are mainly based on increases in number of taller shoots.

The magnesia treatment, however, showed a definite trend, causing many shoots to attain less than average length. If all shoot lengths are divided into length-classes of 1 ft., 2 ft., and 3 ft., all magnesia treatments are seen to have the largest number of tillers in the first class. The typical stunted and bushy appearance of the magnesia-treated plants confirms this finding.

(b) *Leaf analysis* : (Table 4).

(i) Phosphate uptake. Lime exerted a marked positive effect on the uptake of phosphate, nearly double the amount being taken up as a result of liming. Potassium exerted a slight depressing effect on phosphate uptake, whilst magnesium exerted no apparent effect.

(ii) Potassium uptake. The potassium level in the leaves was raised by 25 per cent. by the potash treatment and even more by potash in combination with lime. Lime alone only slightly increased the uptake of potassium. Magnesia exerted a slight depressing effect.

(iii) Calcium uptake. The differences in uptake of calcium caused by the various treatments were very small, although potash seemed to have reduced the calcium uptake slightly.

(iv) Magnesium uptake. Here again the variations in uptake were not very distinct. Lime showed a tendency to increase magnesium uptake.

Discussion. The most outstanding feature of this analysis was the impressive increase of phosphate uptake caused by liming. As the supply of phosphate in all treatments was abundant (15 grams water-soluble P_2O_5 per plant), the action of lime cannot be explained by an increase in the amount of available phosphate in the soil, but only by an improved functioning of the roots. The second important finding is the distinct response in terms of potassium uptake caused by the application of potash fertilizer, which, in conjunction with lime, was even more effective than when added alone. Although sugar-cane is able to store luxury amounts of potassium in its leaves when abundantly supplied with available potash, this is not likely to be the case here as the higher potassium level in the leaves coincides with a highly significant weight response. Liming without potash treatment did promote the potassium uptake to a lesser extent, probably by promoting efficiency of the roots.

Magnesia dressings did not show any striking effect on the uptake of the other nutrients.

(*c*) *Plant analysis* : (Tables 5 and 7).

These figures confirm in a very convincing manner trends indicated by leaf analysis.

(i) Nitrogen uptake. The utilisation of nitrogen was greatly stimulated by the potash fertilizer. Lime alone also seems to have a stimulating effect, but, in combination with potash, this disappears. Its overall effect shown in Table 7, is negligible. The magnesia treatment in all combinations and alone had a depressing effect on the nitrogen utilisation.

(ii) Phosphate uptake. Here the lime treatment was again the outstanding factor and doubled the total uptake of P_2O_5 by the plant. Potash acted in a similar way, but to a lesser degree. Magnesia caused a depression in all combinations.

(iii) Potassium uptake. Potash dressings doubled the uptake. Lime also encouraged the utilisation of potash resources, and the combination of lime and potash seemed to be the most successful of all fertilizer combinations. Magnesia again caused a depression.

(iv) Iron uptake. The uptake of iron was greatly increased by the potash treatment, nearly a threefold amount of iron being taken up in comparison with the control. Lime exerted a similar influence, but the combination of lime and potash caused an increase in the iron uptake of almost 400 per cent.

TABLE 6. *Summary of Table 2*

	Tiller-count		Total lengths of shoots		Average lengths of shoots	
	number	index	metres	index	metres	index
K_0	199	100	79.9	100	0.402	100
K_1	223	112	90.3	113	0.405	100.7
L_0	205	100	82.1	100	0.400	100
L_1	217	106	88.1	106	0.406	101.5
M_0	201	100	84.1	100	0.418	100
M_1	221	110	86.1	102	0.389	93

TABLE 7. *Plant Analysis.* (*Summary of Tables 2 and 5*)

TREATMENT	Percentage effect on fresh weight	EFFECT ON TOTAL UPTAKE OF NUTRIENTS			
		Percentage Increase or Decrease			
		N	P_2O_5	K_2O	Fe
Potash	+17	+18	+17	+105	+100
Lime	+9	—2	+93	+13	+66
Magnesia	—6	—23	—13	—22	—13

Discussion. In Table 7 the figures from Table 5 are combined as overall treatment effects and the increases or decreases due to treatment are expressed as percentages of the zero treatment. For comparison the overall treatment effects on fresh weight are also quoted from Table 2. No treatment gave an increase of fresh weight greater than 17 per cent. and no decrease greater than 6 per cent. For this reason it is clear that, apart from the potash effect on nitrogen and phosphate uptake which is similar to the potash effect on fresh weight, all the other great variations in total nutrient uptake cannot be explained by weight differences but mainly by the concentrations of the nutrients in the analysed material.

It is of particular interest to note that magnesia exerts its detrimental effect mainly by impeding the utilisation of the other nutrients. On intrazonal soil types with high magnesia content this might prove to be a harmful factor. Comparing the effects of magnesia treatment with and without potash and lime, it seems that the toxic effect of the magnesia is somewhat moderated by lime and potash treatments.

The peculiar effect of potash, and to a lesser degree of lime, on the uptake of iron is also noteworthy. The accumulation of iron in various parts of the plant has often been related to potassium, calcium or phosphate deficiency, or to acidity, as is stressed by Dillewijn (1952). By iron toxicity is meant the unequal distribution and accumulation of iron in the nodes rather than the total concentration. The Kalimati disease in Java is attributed by Wilbrink (1931) to potassium deficiency, and by Koningsberger and Van den Honert (1931) to iron toxicity. Potash applications cured the disease in many instances. In the writer's opinion, the real cause of the trouble is to be found in the " acid complex " of the soil, and in many instances an acid soil will also be deficient in phosphate, calcium and potassium, as is the case in this tropical podzolic soil. The prevalence of trivalent aluminium ions in this highly acid soil may seriously damage the cell protoplasm of the roots and disturb the proper functioning of its semi-permeable membranes. The plant is protected from permanent damage by a general die-back of all roots, resulting in a reduced active root surface area, and also by the precipitation of the excessive amounts of aluminium and iron in the roots and vascular bundles. In these circumstances, nutrient deficiencies of the soil are highly accentuated. It is suggested that the introduction of large amounts of potassium and calcium ions into the soil restores the ionic equilibrium around the roots and helps them to function in a normal way. The foregoing experimental data seem to support this view.

Recommendations

This soil should be limed, and the lime thoroughly worked into the top 12–18 inches of soil, before planting, until the reaction of most of this layer which is so important for root development, lies around pH 6.5. Only under these conditions are economic and efficient use of expensive fertilizers possible and better juice qualities with higher phosphate contents to be expected. In addition to this, moderate potash dressings to ratoons might provide a promising subject for further field experimental work.

Summary

A short term pot test with sugar-cane on a typical cane soil in Trinidad is described, potash, lime and magnesia being the factors under investigation.

Responses to treatments were measured as fresh weights, number and total length of shoots ; and leaf and plant analyses were also carried out. These analyses revealed distinct metabolic reactions to treatments.

Potash applications increased the fresh weight and length of shoots, the uptake of nitrogen and phosphate and greatly increased the uptake of potassium and iron. Potash also increased the yield response to lime. The data suggests that potash promoted the utilisation of other nutrients in addition to its direct effect.

Liming increased fresh weights but did not accentuate yield response to potash fertilizers. The uptake of phosphate was doubled. Alone and in

combination with potash, lime greatly increased the uptake of iron. Its overall effect on nitrogen uptake was negligible. The toxic effect of the magnesia treatment was moderated by lime. Calcium uptake was not increased. The main effect of liming is believed to be the restoration of impaired root-functioning under the acid-toxic soil conditions and it is especially successful in combination with a potash dressing.

Magnesia generally depressed growth and nutrient uptake. Uptake of nitrogen and phosphate was especially reduced resulting in stunted growth. Thus magnesium might prove to be a hidden harmful factor in certain soil-types in which this element is over-dominant in relation to the other cations.

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EXPERIMENTS ON THE BANANA BORER, *COSMOPOLITES SORDIDUS*, IN TRINIDAD, B.W.I.

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INTRODUCTION

THE biology of the banana borer, *Cosmopolites sordidus* Germ., has been reviewed by Cuillé (1950). Chauvin and others, (1951) have reported on methods of control and propose the use of banana pseudostem traps treated with a toxic dust called Cosmopolicide-109. This consists of a finely divided dust* as carrier for chlordane, a trace of parathion and an attractive substance, 2-phenyl-4-hydroxyquinazoline. This substance is said to be attractive only by direct contact ; its function is to counteract the repellent effects of the dust and the insecticides and thus to cause the weevils to remain long enough in the treated traps to receive a lethal dose of insecticide. The same workers report upon the use of insecticide treatments of the soil around the banana plants ; experiments in the French West Indies and in French West Africa showed that gammexane and parathion, though toxic to the adult weevils, were too quickly leached or decomposed to offer a practicable control.

The experiments reported here are concerned with the efficacy of Cosmopolicide-109 and with the use of Aldrin and Dieldrin as soil insecticides. Another weevil, *Metamasius hemipterus* L., was frequently taken in the traps and its presence was recorded. *Metamasius* is a more active insect than *Cosmopolites* and has less specific food preferences ; it is a minor secondary pest of many plants and, so far as is known, causes no primary damage to bananas though it may accentuate damage by *Cosmopolites*.

MATERIALS AND METHODS

The banana traps used were made from pseudostems of *Musa balbisiana* throughout the experiments reported here. Pieces about 45 cm. long were cut, split lengthwise and each half was bound near the ends with two twists of wire to prevent disintegration. In the first half of Experiment 1 a smaller trap was used, made from two transverse sections each about 5 cm. thick in which grooves had been cut upon the contiguous faces. This is a type of trap commonly recommended, but it was found unsatisfactory in that it falls to bits in about a week whereas the larger trap (adopted as a standard by Chauvin *et al.* 1951) lasts for over a month.

*Described as " magnesie " but on analysis found to consist mainly of calcium carbonate and calcium sulphate plus a silicate, perhaps kaolin.

The 2-phenyl-4-hydroxyquinazoline (abbreviated hereafter as 2P4HQ) was made up as a solution in ethyl alcohol (following Vilardebo in Chauvin *et al.* 1951, p. 121) since it is insoluble in water. Cosmopolicide-109 was applied at the rate of 10 gm. per trap.

Aldrin and Dieldrin were obtained as Aldrex 2 (2 lb. active material per U.S. gallon of concentrate) and Dieldrex 15 (1.5 lb. active material per U.S. gallon). They were mixed with water and applied from a knapsack spraying machine to the soil immediately around the plants, sometimes also to the soil in the planting hole.

Significance of variance ratios and χ^2 is indicated by the convention :* =5%: **=1%: ***=0.1%. For purposes of analysis of variance of numbers of insects the transformation $\sqrt{x+0.5}$ has been used because the actual observations are likely to be distributed in a Poisson fashion.

Results

Experiment 1 *The attractiveness of various traps*

This experiment was laid out in old bananas preserved as shade for young cacao trees. Several different banana varieties were represented. There were six replicates, each consisting of a group of four traps treated thus :

1. Control, untreated ; 2. Treated with Cosmopolicide-109 (10 gm. per trap) ; 3. Treated with 2P4HQ (2/3% in alcohol, 30 c.c. per trap) ;

Table 1—*Experiment* 1—*Attractiveness of various traps. Treatment* 1—Control, untreated ; 2—Cosmopolicide-109 ; 3—2P4HQ in Alcohol ; 4—Alcohol

	Totals caught in treatment number				Analysis of variance of $\sqrt{x+0.5}$			
					Variance Ratios			
Species	1	2	3	4	Treatments	Blocks	C.V. %	Conclusions
Cosmopolites	50	1	55	40	14.3***	2.0	28.8	1, 3, 4> 2
Metamasius	32	10	85	54	21.5***	5.9**	20.5	3, 4,> 1> 2

Frequencies with which one treatment exceeded another at the same site at the same time

Comparison		*Cosmopolites*			*Metamasius*		
a	*b*	$a > b$	$a < b$	χ^2 (1:1)	$a > b$	$a < b$	χ^2 (1:1)
1. Control ...	2. 109 ...	29	1	26.1***	19	7	5.54*
1. Control	3. 2P4HQ	30	33	0.14	12	47	20.8***
1. Control	4. Alcohol	29	20	1.65	18	32	3.92*
3. 2P4HQ ...	4. Alcohol	33	23	1.79	43	23	6.06*

4. Treated with alcohol (30 c.c.). Traps were retreated on the ninth day and replaced by new traps on the seventeenth day. Records were taken daily for 34 days, the insects being removed and liberated. Results are summarized in Table 1. The two forms of analysis give essentially identical conclusions : *Cosmopolites* is repelled by Cosmopolicide-109 but indifferent to alcohol and 2P4HQ in alcohol ; *Metamasius* is also repelled by Cosmopolicide-109 (though perhaps less strongly than *Cosmopolites*) but is attracted by alcohol and 2P4HQ.

Experiment 2, on retentiveness of various traps, described below, qualifies the results of this experiment by suggesting that Treatment 2 (Cosmopolicide-109) may have had roughly three times as many visitors as the collections revealed. Even if this were so (or even if four out of five visitors left the traps before morning) and even if all the visitors died, traps treated with Cosmopolicide-109 would still be much less effective than untreated traps placed in competition with them.

Experiment 2. Retentiveness of various traps

This experiment was laid out in a cocoa field some distance from bananas. Twenty traps were laid out, 10 untreated and 10 treated with Cosmopolicide-109, treatments being applied at random. Five Cosmopolites were placed in each trap and left overnight ; those remaining were counted the following morning. The experiment was performed four times, twice starting in the morning and twice in the evening. Thus eighty counts of borers remaining were made. Results are summarized in Table 2. Evidently Cosmopolicide-109 repels the borers ; the difference between morning and evening placement

TABLE 2—*Experiment 2—Retentiveness of two kinds of trap. Percentages of borers retained in traps with (in brackets) frequencies of retention of more than one-half (+) or less than one-half (—) of the original samples of five borers per trap*

Treatment	Time of placement	
	Morning	Evening
109	69 (15 + 5—)	34 (4 + 16—)
Control	63 (14 + 6—)	79 (16 + 4—)

Analysis of frequencies

Item	D.f.	χ^2
Treatment	1	6.37 *
Placement	1	4.27*
Heterogeneity	1	8.91**

is probably due to the fact that *Cosmopolites* is largely nocturnal in activity. Those placed in the traps in the morning were mostly killed or inactivated before making an effort to escape ; those placed in the evening, at the onset of their normal period of activity, were more likely to escape before the insecticide took effect.

The implications of this experiment for the conclusions drawn from Experiment 1 have been set out above.

Experiment 3. *Age of Trap*

The impression was gained while conducting Experiment 1 on the attractiveness of various traps that fresh traps were more effective than old ones and Experiment 3 was set up to test this point. The same site as for Experiment 1 was used ; there were ten replicates each of three treatments—Old, Medium and Young traps. The experiment was divided into four periods of nine days each and each period started with the three ages of traps respectively 18, 9 and 0 days old ; at the end of the nine-day period, the Old traps (27 days old) were discarded, the Young and Medium became respectively the Medium and Old and new Young traps were added. Insects

TABLE 3—*Experiment* 3—*Age of trap.* Old—19–27 days; Medium—9–18 days Young—0–9 days

	Totals caught			Analysis of variance of $\sqrt{x + 0.5}$			
				Variance Ratios			
Insect	Old	Medium	Young	Treatments	Blocks	C.V. %	Conclusions
Cosmopolites	24	51	125	10.5***	2.7*	35.7	Y > M, O
Metamasius	2	17	268	24.4***	2.0	25.8	Y > M > O

Frequencies with which one treatment exceeded another at the same site at the same time

Comparison		*Cosmopolites*			*Metamasius*		
a	*b*	*a* > *b*	*a* < *b*	χ^2 (1 : 1)	*a* > *b*	*a* < *b*	χ^2 (1 : 1)
Old	Medium	18	40	8.34**	2	15	9.94**
Old	Young	13	82	50.12***	1	134	131.0***
Medium	Young	30	76	19.96***	8	130	107.9***

were collected daily with the results shown in Table 3. Young traps were about five times as effective in attracting *Cosmopolites* as old traps ; *Metamasius* shows the same preference but even more strongly.

Table 4 gives the results of this experiment and of Experiment 1 classified by three-day intervals. Data for Experiment 1 are divided into two groups, A and B, referring respectively to the first and second periods of the experiment. Period A began in the end of the dry season ; catches were low and the period of maximal attractiveness for both *Cosmopolites* and *Metamasius* lay between four and nine days. Experiment 1 and the whole of Experiment 3 were carried out in wet weather ; borer activity was much greater and maximal attractiveness of the traps was earlier (one to six days).

TABLE 4—*Numbers of weevils caught in traps of various ages*

Experiment	Insect	Age of Trap (Days)								
		1–3	4–6	7–9	10–12	13–15	16–18	19–21	22–24	25–27
1A	*Cosmopolites*	4	8	18	13	3	9	—	—	—
	Metamasius	10	16	16	7	3	2	—	—	—
1B	*Cosmopolites*	31	25	7	9	12	8	—	—	—
	Metamasius	71	28	8	2	6	2	—	—	—
3	*Cosmopolites*	33	53	39	18	26	7	8	13	3
	Metamasius	96	100	52	6	7	4	2	0	0

These results do not agree with the statement of Cuillé (1950, p. 69) that old traps are more attractive than young ones. His results, though hardly amenable to detailed analysis, are no more than slightly suggestive of the effect he claims ; they were evidently based on laboratory rather than field experiments.

Experiment 4. *Control of Cosmopolites by means of Aldrin and Dieldrin*

Plantains were chosen for this experiment because they are particularly susceptible to attack by *Cosmopolites*. Plantains are a taxonomically distinct group of banana varieties which are characterized by the high starch content of the ripe fruit ; this makes them unpalatable as dessert bananas but they are widely used and esteemed throughout the tropics as a cooked vegetable. In Trinidad they command a higher price than other bananas and this is virtually solely a consequence of restriction of cultivation by *Cosmopolites*. It is common experience that one crop of fruit can be expected before a new planting goes down to borers ; thereafter many pseudostems fall before shooting and others before the bunch matures ; to reap any fruit from an infected stool is exceptional. If plantains are planted among standing bananas there is little hope of reaping any fruit. Plant sanitation measures are usually recommended as a control and doubtless would prolong the life of a new planting if thoroughly carried out but they probably cannot give complete protection over a period of years. Trials with Aldrin and Dieldrin were therefore begun and some results are reported here.

Preliminary observations were encouraging. Old plantain stools which had not matured a bunch in the previous three years were treated. A more or less arbitrary choice of mixture (4 parts Dieldrex 15 : 3 parts Aldrex 2) was made and it was applied at the rate of 2 lb. of active material per acre concentrated in the soil immediately around the banana plants. The effect was immediate, for two bunches already shot were carried to maturity and several subsequent shootings matured successfully. The plants were retreated a year later and, so far, no signs of borer damage have been discerned. Two fallen stems were dissected but were not infested ; they had apparently " grown out of the ground " and had been blown over or borne over by the weight of a bunch. Recent plantings have been treated as a routine with entirely satisfactory results.

Of the many seedling banana families raised at the Imperial College of Tropical Agriculture for genetical and breeding work, some appeared to be rather susceptible to borers. In a small seedling, attack is usually fatal because a single larva can eat out a large part of the corm and growing point and set up secondary rots from which the plant has no chance of recovery. Satisfactory protection has been achieved by yearly treatment with the same mixture as above applied at the same rate. It has proved feasible to make up the stock mixture, dilute 350 c.c. of it in a knapsack spraying machine and treat some 20–40 plants according to the spacing. The amount applied to each plant can easily be gauged after a little practice by counting seconds. One man working on level land close to a water supply can treat an acre of seedlings in about four hours. An acre of hilly land or of larger plants would take longer but it is clear that the labour requirements of Aldrin-Dieldrin application are slight.

With these preliminary observations in mind, a small experiment was set up using a group of twelve plantains divided into six pairs of contiguous plants. Within each pair one plant was treated at planting time ; the other was untreated. Treatments were repeated a year later. Of the six untreated plants, four died before establishment and were replaced by supplies of which two died ; after 20 months one bunch had been reaped and one plant was in bearing. Of the six treated plants, by contrast, none died and after 20 months all had shot, two having been reaped. The fact that two untreated plants bore fruit was unexpected ; probably they were to some extent protected by proximity to treated plants. The use of much larger plots would be desirable in experiments of this kind but the results here seem decisive nevertheless. It is established that plantains in Trinidad (and probably elsewhere in the wet tropics) can be protected against the attacks of borers by yearly applications of an Aldrin-Dieldrin mixture.

Discussion

Poison trapping as a means of control of the banana borer

The method of poison trapping with Cosmopolicide-109 recommended by Chauvin and others (1951) is, as their experiments show, an effective means of

killing banana borers. It is, however, an impractical means because (*a*) it demands the use of more pseudostem material than the field can produce (as Vilardebo in Chauvin and others (1951) recognized) and (*b*) it makes considerable labour demands in cutting, preparing and placing traps. The first consideration is critical ; the method demands the placing of two traps per banana stool ; each stool can produce (at normal commercial pruning) one pseudostem or roughly nine traps per year; a trap lasts about one month in the wet season and therefore roughly 20 traps per stool per year are required. At best, a field could be trapped for about half the year unless the intensity of trapping were to be reduced or pseudostems were to be carried in from other fields (leaving them destitute of material from which to make traps). Why such an impracticably high intensity of trapping should be necessary is suggested by the experiments reported above ; 2P4HQ is either unattractive or, at most, slightly attractive* to *Cosmopolites* in the field and the compound, Cosmopolicide-109, is highly repulsive (though undoubtedly toxic). The proposed system of poison trapping based on Cosmopolicide-109 is, in effect, therefore a general insecticidal treatment of all available banana pseudostem material in the field. Viewed in this light it would be expected (as it does) to kill some borers but not to kill them all nor to prevent egg laying by surviving adult females in the bases of the banana stools. An efficient poison trapping method would have to incorporate an olfactory attractant so powerful that virtually all adults were drawn to it and killed before the females could lay eggs.

Insecticidal treatments

The insecticidal treatment proposed here has the advantages that (*a*) it is cheap and simple to apply and (*b*) it can be applied in the most valuable place, namely, in the immediate vicinity of the banana stool, thus preventing egg laying by the females. Adults may survive in the untreated strips of soil between the banana rows and yet do no damage. The chief difficulty has been to find an insecticide sufficiently persistent for use in soil in the wet tropics. Gammexane and Parathion were too rapidly leached or decomposed to be useful (Chauvin *et al.* 1951). Aldrin and/or Dieldrin, as reported here, seem to be much more promising and banana borers can undoubtedly be controlled by means of them. More information is required on dose and persistence but it appears at present that a yearly dose of 2 lb. of active material per acre is of the correct order of size. Doubtless, treatment could be somewhat relaxed after the borers in an area had been brought under control.

Summary

Field experiments on the banana borer, *Cosmopolites sordidus*, are described. The relative merits of a recently proposed system of poison trapping and of certain insecticidal treatments are assessed and it is concluded that the latter are cheaper and more effective. It is shown that, contrary to

*It is, most probably, slightly attractive by contact because (1) *Metamasius* is attracted by 2P4HQ in the field (Experiment 1, above) and (2) there is no evidence of olfactory perception in Y-tube experiments made in the laboratory.

previous statements in the literature, the attractiveness of banana pseudostem traps to banana borers is greatest in the first week and thereafter declines. Some information is also given on another weevil, a secondary parasite of bananas, *Metamasius hemipterus*.

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A TAINT IN COWS' MILK CAUSED BY THE GRAZING OF *ISCHAEMUM ARISTATUM* L.

BY

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Literature Review

Ischaemum aristatum L., appears to be a native grass of tropical Asia. It has been recorded from India, Ceylon, China and Malaya (Blatter & McCann 1935), and from Burma (Rhind 1945). During the past decade *I. aristatum* L., has been introduced into various other parts of the tropics and has been reported in the West Indies, British Guiana, West Africa, Mauritius and Fiji.

As might be expected it is known under a great number of vernacular names, but in Trinidad it is commonly referred to as 'Tabaquite' or 'Toco' grass. The species arrived in Trinidad from Hong Kong as seed in the straw of packing cases consigned to the now defunct oilfield at Tabaquite in Central Trinidad. It was discovered there as a strong sward several years later by Dr. J. L. Shannon, Veterinary Officer to the Trinidad Government. A large area of an estate at Toco was subsequently planted with this new introduction, from whence most of the present planting material in Trinidad has emanated.

Ischaemum aristatum L., is drawn and described in detail by Blatter and McCann (1935). Joshi & Phillips (1953) in the Bombay State of India, Rhind (1945) in Burma and Parham (1949) in Fiji report the feeding of this grass to cattle. It is believed however that these writers refer only to the feeding of this grass as a wayside or pasture weed and not to the grazing of pure stands or mixtures with legumes. Barrie-Smith (1950) refers to the successful grazing of pure stands of *Ischaemum aristatum* L., by horsekind in Trinidad. Pure stands of the same species have also been fed successfully to horsekind and ruminants at the Imperial College of Tropical Agriculture where it has been found to withstand heavy grazing, particularly during the wetter parts of the year (Howes, Campbell & Badcock, unpublished).

Detection of the Milk Taint

In October, 1952 complaints about a milk taint began to be received in ever increasing numbers by the dairy of the Imperial College of Tropical Agriculture. In an immediate investigation of the possible causes, the following were eliminated:—

(1) An ailment or disease of any animal.

(2) Bacterial infection of the milk subsequent to its withdrawal from the udder.

(3) Oxidation effects caused by treatment and storage.
(4) Faulty processing of the milk.
(5) Contamination due to faulty cleaning of dairy equipment.
(6) The emission of strong odours by materials in the immediate presence of the milk.
(7) Any individual ingredient of the concentrate ration fed to the milking stock.
(8) Weed species in the pastures or the cut grass fed to the milking stock.

After a period of a few weeks it was noticed that the incidence of the complaints coincided with the use of the only pasture of *Ishcaemum aristatum* L., in the rotational grazing programme. Several feeding trials were then conducted in which varying numbers of cows were fed *I. aristatum* L. Zebu and taurus cattle together with various grades of cross-bred animals were all used in these trials which confirmed the earlier suspicion.

Grass from the College plot of *Ischaemum aristatum* L., was fed to milking cows at the Government Stock Farm and the taint was again detected. In order to ascertain that it was not grass from the College pasture in particular which was responsible for the taint, quantities of the same grass were cut from two plots several miles apart on the Trinidad Agricultural Experimental Station at Centeno. This grass was fed to milking animals at both the College and Government Stock Farm with the same results.

During the period from October, 1952 to September, 1953, grass from the three fields already mentioned was fed at varying intervals and milk taints were detected on all occasions. Milk from cows fed *I. aristatum* L., was processed separately and passed to unsuspecting customers previously selected at random. Spontaneous complaints were received from customers who were allocated the suspected milk but no complaints were received from customers who had obtained similarly processed milk from cows fed other grass. While some persons objected strongly and requested a replacement of the milk, others merely intimated that a flavour was noticeable but that the milk could be conveniently used for cooking purposes.

The taint is difficult to describe, the terms 'sour', 'yeasty' and 'akin to molasses' all having been used. Upon opening a batch cooler in which large quantities of tainted milk had been stored overnight, a pronounced odour of garlic may be detected. In all cases it appeared that the flavour tended to be directly related to the quantity of *Ischaemum aristatum* L., fed. Small quantities of this grass mixed together with larger quantities of other grasses did not appear to cause a taint, but as the quantity of *I. aristatum* L., increased the taint developed and became more and more pronounced.

Distinct differences in flavour were discernible in milk drawn from two succeeding milkings of cows which had in the interval been fed *Ischaemum aristatum* L. On one or two occasions the flavour was detected in milk drawn

from cows fed *I. aristatum* L., some twelve to twenty-four hours previously. However this taint was not detected if the grass had been eaten more than twenty-four hours previously.

The objectionable flavour was noticed as being more pronounced when the grass was fed in the flowering stage which occurs in Trinidad from October to January. It is also interesting to note that when one walked through a plot of this grass, particularly in the flowering stage, it emitted an odour similar to that sometimes detected in the milk, The odour is also pronounced when a growth of several inches of this grass has been cut and left in the field to cure as hay. A similar phenomenon is also exhibited in temperate areas by the Coumarin of newly mown hay. Attempts have been made to isolate the chemical agent responsible for the taint, but to date these efforts have all proved unsuccessful.

Discussion of Results

This particular taint of milk is unlikely to have been noticed previously in Trinidad since only non-milking stock has been kept on the few available pure stands of *Ischaemum aristatum* L. The pure stand of this grass as grown at the Imperial College was not grazed to any extent by milch stock before October, 1952.

It is interesting to speculate why this milk taint has not been reported from areas such as Bombay and Fiji where the grass has existed in pasture for several years. It is most likely that in these areas *Ischaemum aristatum* L., exists as but one grass amongst many in a mixed sward, in which case it would probably not be consumed in sufficient quantities to cause a taint. It is also possible that different strains of *I. aristatum* L. exhibit different effects on milk flavour, the Trinidad strain being unfavourable. Warner (1951) has pointed out that the strong flavour of many tropical dairy products is caused by the use of primitive processing methods. Such strong flavours could mask any comparatively delicate flavour such as that reported here.

No tests have been made with goats' milk but since the odour and flavour of goats' milk is more pronounced, it is unlikely that this taint could be detected. However it is proposed to undertake some tests with goats' milk in the near future.

It was thought that other members of the genus *Ischaemum* might have a similar effect on milk flavour. Since no other species of *Ischaemum* were available in Trinidad a feeding trial was carried out at the Government Stock Farm in British Guiana where "Lucuntu" grass, *Ischaemum timorense* (Kunth), C. E. Hubbard, was exclusively fed to milking stock. No taint in the resultant milk was reported (Croucher, personal communication).

Summary and Conclusions

(1) A taint in milk is reported which is caused by the grazing of a pure stand of the Trinidad strain of *Ischaemum aristatum* L.

(2) The reported taint is accompanied by an undesirable odour, the intensity of both depending upon the quantity of the *Ischaemum aristatum* L., consumed and the time which has elapsed since feeding.

(3) It is suggested that in tropical areas where *Ischaemum aristatum* L., is grown, dairymen should investigate the effects of their particular strain on the flavour of milk.

(4) It is considered unwise to contemplate any further plantings of the Trinidad strain of *Ischaemum aristatum* L., for dairy cattle. Those pastures now in existence should be utilised only by beef and dry or growing dairy stock.

(5) For grazing purposes in the wet tropical areas of the West Indies the closely related species *Ischaemum timorense* (Kunth), C. E. Hubbard, known in British Guiana as "Lucuntu" grass, is suggested as an alternative. This species is agronomically similar to the Trinidad strain of *I. aristatum* L., but does not possess its undesirable properties.

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THE VISUAL ASSESSMENT OF CURED CACAO

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The assessment of cured cacao by visual means offers several difficulties, owing to the number of different criteria which affect the commerical value of the crop. Moreover, wide differences exist between cacaos prepared in different areas, and each area has its own peculiar standards by which its cacao should be judged. The intention of this paper is to offer suggestions as to the best procedure for examining prepared cacao for the purpose of assisting the producer to improve his product. For the reason mentioned above, it is not proposed to attempt to specify standards of universal application.

Most cacaos vary so widely that a large sample is required to secure any degree of precision in assessment. However, with very large samples, the examination becomes more lengthy and tedious than is justified by the results. It is suggested that a sample size of approximately 150 grams is adequate. Some precaution is essential to secure a representative sample, both with regard to bean-size and degree of fermentation, particularly where batches from several fermentations have been combined. In particular, it should be noted that dry cacao shows a "sorting" tendency when piled or shaken up, larger beans tending to congregate nearer the bottom. It is therefore not sufficient to agitate the bulk of material and then draw the sample from the top. For large bulks of cacao, the best procedure is probably to withdraw a large sample by some process of random selection, and then to subsample this by repeated quartering.

The sample as received is not a static entity. The smaller the size of the sample, the more rapidly do its characteristics change, and the less does the sample resemble the material it is supposed to represent. Insect infestation spreads very rapidly through a small sample, and, because the relative exposed surface area is larger, moisture content is subject to larger and more rapid changes.

It is therefore necessary to examine the sample as soon as possible after its withdrawal from the bulk. If it is proposed to preserve the specimen for longer than two or three days, it should be kept in cold store, or dried out (most suitably at 50°C. for 48 hours) and kept in a sealed metal or glass container and examined frequently.

External Examination

The external appearance of cacao depends upon the method of preparation: thus, Trinidad cacao has a dark-brown polished appearance, due to the process of "dancing" customary during drying; the washed cacaos of the Pacific are pale red-brown in colour, and so on. It can be said, however, that a well-prepared cacao should be fairly uniform in appearance, and any great unevenness in the external colour suggests a corresponding variation in the preparation, such as for example, lack of thoroughness in mixing during fermentation. The aroma of cacao is normally characteristic and not unpleasant, an unpleasant odour being usually traceable to some fault in preparation or storage. Incompletely fermented cacao frequently has an unmistakeable odour of acetic acid, while unsatisfactory drying or storage conditions can produce a range of unpleasant odours of musty, earthy or putrefactive types. The high fat-content of cacao renders it strongly absorptive towards external odours, which are retained tenaciously, sometimes to appear ultimately as a taint in the processed material.

Damage, involving perforation of the testa, is an important index of the care taken in preparing the cacao. A damaged bean is not only very prone to destruction by insects; but also becomes a danger to the intact material, since it provides a focus for insect and mould attack, both of which have grave effects if allowed to spread throughout the cacao. Each individual bean in the sample should therefore be examined for damage entailing perforation of the testa. Three basic types of damage can be distinguished, as follows:

(*a*) Mechanical injury, usually of two kinds: (i) cuts produced during the opening of the pod, and (ii) cracks caused by rough handling after drying. The difference between these two kinds of injury is readily apparent on inspection.

(*b*) Penetration of the testa by the radicle of the bean. The radicle shrinks during drying, and may fall out, leaving a circular hole at the base of the bean, approximately 2 mm. in diameter. This type of damage occurs where pods are harvested in such an over-ripe condition that germination has taken place in the pod. To a much smaller degree, it may be found in underfermented cacao, due to low temperatures during fermentation (De Witt, 1952).

(*c*) Insect damage. Insect attack is characterized by small holes in the testa, of the order of 1 mm. in diameter and usually surrounded by granular frass. On opening the bean, more frass can be seen in tunnels in the cotyledons. Usually, in an infested sample, many beans are found having debris adhering externally, without entry having been made to the interior of the bean. It is therefore necessary to remove the frass and examine the testa for signs of penetration. The cacao moth, *Ephestia cautella*, is a common pest of stored cacao. Where infestation is due to this insect alone, only previously damaged beans are attacked, since it cannot penetrate the intact testa. The cigarette beetle, *Lasioderma serricorne*, and the cacao weevil, *Araecerus fasciculatus*, on the other

hand, can attack sound cacao, and it is these last two, therefore, that are primarily responsible for insect damage to otherwise intact beans. When a bean has been attacked by weevil or beetle, however, it becomes vulnerable to moth attack through the punctures in the testa (Cotterell *et al*, 1952). In heavily infested samples, all, or nearly all the damaged cacao will be attacked by insects. The degree of attack on undamaged beans depends upon the presence of beetle or weevil, and generally appears to occur at a rather later stage than moth attack on damaged beans.

The incidence of weevil attack is associated with moisture content, its optimum being at 12–15 per cent. moisture, and some measure of protection is afforded by drying cacao to a level of 8 per cent. moisture. Care in handling, so as to prevent mechanical damage, limits the attacks of cacao moth. The deleterious effect of insect attack is the loss of cacao which it entails. Since the frass and insect remains are separated from the useful material by the winnowing process in the course of manufacture, this defect reduces the value of the cacao simply by virtue of the fact that it contains less usable "nib", in contrast to the effects of mould infection mentioned below, where a high level of infection may render the cacao useless for edible purposes and fit only for fat-extraction.

For general purposes, it is suggested that damage be expressed as the percentage of the total number of beans (i) mechanically damaged or germinated, (ii) attacked by insects, whether or not originally damaged, and that the damaged beans be counted first and then discarded from the sample.

The Bean Size

The size of the individual bean is of great interest to the buyers, the main reason being that the larger the bean the lower the proportion of shell (testa) in the total weight. However, the weight distribution is as important as the mean weight of bean. Not only is a large bean-size desirable, but also a high degree of evenness in bean size. The reason is that both in fermentation and in processing at the factory ideal conditions depend to a certain extent on the size of bean: the more uniform the beans, the nearer is it possible to approach ideal conditions. The bean size determination, therefore, should include both a measurement of the mean weight of bean, and an estimation of the size distribution in the sample.

The size determinations are most conveniently carried out on 100 beans randomly selected from the sample after discarding the damaged beans. The average bean weight is determined from the weight of this sub-sample, which is then divided into weight-classes. The number and size of the classes is purely arbitrary, and depends on the characteristics of the type of cacao under examination. Three classes should suffice for normal purposes, with limits chosen to include (i) normal-sized beans, (ii) undersized beans, (iii) waste. In Trinidad cacao, the classes most suitable appear to be (i) above 1.0 gm.

(ii) 0.5–1.0 gm. (iii) below 0.5 gm. A further class, for twinned beans, is also necessary, since most cacaos contain a small proportion of these. Twinned beans are pairs of beans which have remained adhering to each other throughout fermentation and drying. They are, in general, undesirable, since the two beans are usually poorly fermented, particularly around the point of attachment, and frequently mouldy, owing to the slow rate of drying at the place where the two testas adhere. A high proportion of twinned beans can be reduced by sorting during the first day of drying, breaking up any clumps of beans which are found. A tendency to reap immature pods will increase the number of twinned beans, since in such pods the pulp is still fairly solid, and holds the beans together more firmly.

It is not necessary to weigh each bean, since the majority can be sorted by eye but a number of borderline cases may have to be sorted by means of a balance. The distribution can be expressed either as percentage by number, or by weight, whichever is the more convenient for the purposes of the examination. The mean weight and distribution of weight are usually similar for cacao of the same type: deviations from the norm might be due to picking immature pods or the presence of a high proportion of low-grade types of tree on the estate.

Weight is, of course, not the only criterion of size which can be used for comparison of size distributions. In many cases, it will be more valuable and convenient to use a linear measure, particularly in places where it is customary to grade the cacao by means of a mechanical grader and where it is desired to investigate the results of grading on a sample. The beans might then be classified by length, breadth, thickness or transverse cross-sectional area, by using appropriate gauges representing the limits of the classes; calipers for linear dimensions, and apertures of suitable size for the areas. Again, distribution may be expressed as percentage by number, or by weight. It should be noted, however, that to determine grading performance of a sample, the distribution should be calculated as percentage by weight, as this is the measure of the commercial value.

Internal Examination

The usual visual method for estimating the quality of the fermentation is the "cut test." While not altogether satisfactory, this test does provide a rough guide to the care taken in fermentation. One hundred beans are cut longitudinally in half, and the colour and texture of the cotyledons is taken as index of the fermentation. A well-fermented bean is characterized by cotyledons of pale to dark brown colour, according to the amount of purple pigmentation originally present. The texture is crisp, and the cotyledons are separated from each other and not adherent to the testa.

On the other hand, the cotyledons of an underfermented bean retain much of their original pigmentation, have a more or less "cheesy" texture on cutting, and adhere closely to each other, and to the testa. In the extreme case of the unfermented bean, the cotyledons are a muddy slate-blue. The average

fermentation produces a mixture of beans showing characteristics of all kinds intermediate between these extremes, and the standard of the fermentation is therefore best judged by classifying the cut beans into a small number clearly defined types. Owing to the fact that there is no clearly defined borderline between good and bad fermentation there is a tendency to "adjust" whilst carrying out the cut test: hence the necessity for a clear definition of the classes. For most purposes, it is sufficient to divide the beans into "good", "fair" and "bad" beans, with a further class for mouldy beans. The following definitions of the classes are suggested:

"Good" —Brown beans of crisp cut.

"Fair" —Brown beans, cheesy or hard in cut, cotyledons not separated.

"Bad" —Purple or white beans (according to variety) of cheesy or hard cut.

The use of the "cheesy" cut in the diagnosis of underfermentation presupposes that the cacao is satisfactorily dried. If the moisture content of the cacao is high, this in itself will alter the cutting characteristics of the beans. For reasons mentioned below, the moisture content of well-dried cacao should be not greater than 8 per cent. Above 11 per cent., all beans tend to give a cheesy cut (Ciferri, 1951). This factor is of some importance in estimating the resistance of the cacao towards mould infections, and it might be found desirable to determine the moisture content if it is suspected that this is unduly high. The general signs of high moisture content are, as already mentioned, a cheesy, moist-looking cut, a pliable shell and a dull sound, rather than a crisp rattle, when the sample is shaken.

Mouldy beans, whatever the standard of fermentation, are classified separately, since the presence of mould imparts a characteristic taint, which, even in small amounts (3–5 per cent.) renders the cacao useless for edible purposes.

In mouldy beans, a white, green or yellow mycelium can be seen, usually originating at the radicle, and spreading between the cotyledons. In some cases the infection enters through other regions of the testa, presumably by means of minute holes or thinner areas.

Each bean should be classified as it is cut, since the appearance of the cut surface changes rapidly on exposure to the air, due to drying and oxidation. The standard of the fermentation is best expressed by tabulating the percentage of the total number of beans in each class. For well-fermented cacao, the "good" class should include 80-90 per cent. of the total, with the bulk of the remainder in the "fair" class; the proportion of purple and mouldy beans should be small. As already mentioned, more than 3–5 per cent. of mouldy beans is a very serious defect, which greatly reduces the value of the cacao to the manufacturer. Mould infection arises when the moisture content of the cacao is above a critical level which is probably in the region of 10 per cent.

Under humid conditions, dry fermented cacao absorbs moisture, and it is therefore accepted that the safe maximum moisture content for the prevention of mould growth is at 8 per cent. A high level of mould infection may be traced to prolonged storage or to inefficient drying.

With regard to the standard of fermentation, the limits for well-fermented cacao suggested above should be viewed in the light of the normal product of a given area, since the wide differences in fermentation practice in different places cannot be expected to yield the same results in each case. The faults in fermentation technique giving rise to defective beans (De Witt, 1952; Roelefsen, 1947) may be summarized as follows:

(i) Too short a fermentation period. This gives rise to a high proportion of purple beans, with a cheesy cut, and the cacao frequently has an odour of acetic acid.

(ii) Insufficient mixing. Besides giving rise to unevenness in the external colour, the internal appearance is variable, with a high proportion of purple or slatey-purple beans, some of which may show signs of germination. Similar effects may be produced where the bulk of cacao fermented is insufficient.

(iii) Inadequate covering. If the layer of leaves covering the beans during fermentation is too thin, water evaporates rapidly from the cacao at the high temperatures of fermentation and ultimately a stage is reached where the moisture content is so low that the internal processes of fermentation are inhibited prematurely, thus giving rise to underfermented beans.

It should be emphasised that the above is only a brief outline of common faults in fermentation technique and their effects. In general, where the standard of fermentation is found to be poor, it would be necessary to observe the preparation in process to analyse its shortcomings in detail.

Over-fermentation, which may also be observed by carrying out the cut test, is usually general in its effects, nearly all the beans in a fermentation being affected in a similar way. Externally, the testa is very dark brown in colour, and is brittle. The cotyledons are very dark in colour, and the surface is dull, in contrast to the shiny surface seen when a well fermented bean is broken. Over-fermentation is sometimes seen where planters endeavour to reduce the proportion of purple beans by increasing the fermentation time beyond its customary limits. More frequently, however, over-fermentation is the result of fermentation continuing during drying, due to wet weather delaying the reduction of moisture content below that at which it is inhibited.

The results of examinations of fermented cacao from twelve Trinidad estates is shown in Table I. The samples were stored for some time without precautions, and the figures for damage therefore demonstrate the development of insect attack to a high level, as in samples 1, 6, 8, 9, 11 and 12. In those samples which have not suffered severely from insect infestation, it can be seen

TABLE I

Sample	Aroma	Damage		Undamaged Beans								
		Insect	Mechanical	Mean Wt.	Wt. Distribution (%)				Fermentation (%)			
		%	%	gm.	<0.5	<1.0	>1.0	Twins	Good	Fair	Bad	Mould
1	Faint	16.2	—	0.978	9.2	47.9	43.8	—	90	5	—	5
2	Chocolate ...	0.95	2.85	0.962	3.0	39.5	56.5	1.0	90	10	—	—
3	Chocolate, sour ...	0.68	15.6	1.105	2.4	28.2	68.5	0.8	90	10	—	—
4	Very faint ...	—	1.7	1.036	3.3	32.6	63.4	0.6	85	15	—	—
5	Strong acetic ...	1.0	5.3	1.158	3.1	27.9	68.9	—	50	40	10	—
6	Slight acetic ...	10.5	1.2	1.065	3.5	23.1	72.7	0.7	75	20	5	—
7	Faint coconut ...	—	11.2	1.080	1.3	25.8	73.0	—	65	25	—	10
8	Normal	10.5	2.7	1.042	2.3	29.9	65.9	1.8	85	15	—	—
9	Faint aroma ...	16.1	0.7	0.950	2.5	39.5	57.0	—	80	20	—	—
10	Very faint ...	—	0.6	1.047	2.2	27.2	68.8	0.7	65	30	—	5
11	Faint aroma ...	14.7	0.6	1.033	0.4	36.5	62.0	1.1	85	15	—	—
12	Chocolate ...	8.0	0.4	1.056	2.1	31.6	66.3	—	55	40	5	—
			Means	1.043	2.94	32.48	63.90					

that the proportion of mechanical damage varies widely, from the extremes of sample 10 (0.6 per cent.) to that of 3 (15.6 per cent.). This is to be expected, as this figure represents the care taken in handling the cacao. A more detailed analysis of the damage would show the stage at which it had occurred—a high proportion of cut beans shows careless opening of the pod; a large number of cracked beans, either violent handling after drying, or "dancing" with the beans in too dry a state. It will be seen also that in severe insect infestations, nearly all the damaged beans have been attacked.

The bean-size figures show that cacao of this type has a mean bean-weight near 1.04 gm., and a weight distribution of 3 per cent., 32.5 per cent. and 64 per cent. by number. Samples 4, 8, 10, 11 and 12 are average with regard to size. Nos. 1, 2 and 9 show a high proportion of undersized beans, while 3, 5, 6 and 7 are rather larger than the average.

The fermentation figures are given to the nearest 5 per cent. The samples are, on the whole, fairly well fermented, with the exceptions 5, 6 and 12. Of these, 5 and 12 are definitely poorly fermented. Samples 1, 7 and 10 are the only three showing mould infections, and there are grounds for suspicion that Sample 7 has been stored under unsuitable conditions, since it has a perceptible odour of coconut.

The results of the examination expressed in Table I may be summarized as follows:

Sample 1. Well fermented but undersized, heavily insect infested and mouldy.

Sample 2. Well fermented, undersized.
Sample 3. Well fermented, large beans but carelessly handled.
Sample 4. Satisfactory.
Sample 5. Large beans, poorly fermented.
Sample 6. Not well fermented, large beans, heavily insect infested.
Sample 7. Fermentation fair, carelessly handled, very mouldy.
Sample 8. Fermentation satisfactory, heavy insect attack.
Sample 9. Fermentation satisfactory, small beans, heavily insect infested.
Sample 10. Moderate fermentation, mouldy.
Sample 11. Fermentation satisfactory, heavy insect attack.
Sample 12. Fermentation poor, severe insect infestation.

The essential difference between this summary and Table I should here be noted. Table I is "absolute" in the sense that its results depend solely on the cacao itself and not on its type or source. In compiling the summary above, however, the assumption has been made that a mixture of all the samples would give a typical Trinidad Plantation cacao (which is broadly true with the exception of the insect infestation) and the examination results have been judged on that basis. It is not difficult to see, that, if it were known that the mean bean-weight of Trinidad cacao, for example, is 1.2 gm., then all the samples would have been regarded as undersized. In other words, comments on the result of an examination implies a certain amount of prior knowledge of the standards to be expected for that particular type of cacao. This may be taken for granted in the case of an area in which cacao production and export are already well established. Where a small local cacao industry is being expanded to external markets, or where cacao is being introduced, circumstances are rather different, since no such standards exist. There are three major types of fermented cacao:

(*a*) Criollo, having a large plump bean of a cinnamon colour.

(*b*) Trinitario, with a fairly large bean of red-brown or chocolate colour.

(*c*) Amelonado, having small, rather flat beans, of a deep chocolate colour.

The first two classes form the "fine" cacao of commerce, the last the "bulk" or "ordinary" cacaos. The judging standards for a new cacao area will depend upon which of these types is to be grown, and should be based upon the standards for equivalent types of cacao grown elsewhere—i.e., the potential competitors in the cacao market (Urquhart & Dwyer 1951).

Summary

The characteristics affecting the value of fermented cacao, are described, and their determining factors discussed. A scheme is suggested for the examination of cacao for advisory purposes.

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